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Placing Technology: Examining the Emerging Use of Solar Water Heaters in Oaxaca, Mexico

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Placing Technology: Examining the Emerging Use of Solar Water Heaters in Oaxaca, Mexico

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Dedication

To my family, a constant source of inspiration, encouragement, love and support.

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Abstract

Placing Technology: Examining the Emerging Use of Solar Water Heaters in Oaxaca City, Mexico

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This study is an examination of the (broadly envisioned) process that has led to the emerging use of solar water heaters in Oaxaca de Juárez, Mexico. In 2007, Mexico launched a major policy initiative designed to encourage the use of solar water heaters in the residential sector throughout the country. As this policy has been implemented, over one hundred thousand solar water heaters have been installed on new homes and many people are beginning to encounter this technology for the first time. This policy has been successful in placing solar water heaters on the rooftops of new homes, but problems with how some of them are functioning threaten the long-term prospects of diffusion of the technology. The study shows that while solar water heaters have the potential to carry positive environmental and economic benefits at the household level, there are also many potential and actual scenarios in which the technology can have detrimental effects. Drawing on literature from the Diffusion of Innovations, the Social Construction of Technology, Actor-Network Theory, the Multi-Level Perspective on Technological

Transitions, and Ecological Modernization Theory, this paper also seeks to contribute to the literature concerning the overall processes of socio-technical transitions.

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Chapter 1: Technology and Society

On March 11, 2011, a devastating earthquake and a subsequent tsunami struck Japan, causing untold damage and loss of life. Over the next several days, explosions at three nuclear power facilities would trigger nuclear meltdowns and major releases of radioactive materials, placing the surrounding environment and thousands of human lives in serious danger. Less than a year earlier, an offshore oil drilling platform in the Gulf of Mexico exploded into flames, instantly killing 11 crewmen and causing an oil leak that would ultimately spill about 4.9 million barrels of oil into the Gulf of Mexico. In many ways these tragic catastrophes highlight both the relative vulnerability of modern technological systems, as well as the vital role these technologies play in producing the energy that the world depends on.

Often, it is only in the aftermath of technological failures when fundamental questions arise concerning the development of a given technology and its level of integration with broader social, political, and economic systems (Lyon 2001, p.29, Bijker and Law 1994, Law 1992). Questions such as "Why does this technology function in this particular way?", and "How did this technology become such a part of our daily life?" are often only asked when prompted by dramatic failures. A growing body of literature is asking these types of questions about newly emerging technologies, and developing interesting insights about the complex processes of large-scale technological change. By examining the wide range of factors involved in the emergence of new technological systems, we can hopefully gain a better understanding of the nature of the relationship between modern society and the technologies we rely on every day.

Energy related technologies, in specific, are crucial for supporting nearly every technological system of modern civilization, making their relationship with society especially critical to understand. Our agricultural, telecommunications, building, and transportation systems all rely on massive quantities of energy. In fact, all of the dramatic changes in human civilization and lifestyles achieved since the industrial revolution are closely bound to an unprecedented rise of total energy consumption, based primarily on fossil fuels (Smil 2003). Yet the fossil fuel sources of energy we currently rely on are indisputably irreplaceable and also pose significant environmental concerns.

As these growing environmental problems have become an important part of the discourse on energy, a wide variety of government policies and programs, at scales from the local to the global, have attempted to promote the use of alternative energy technologies. These programs have achieved varying degrees of success, but have also created guidelines and empirical accounts concerning the different policies that can be enacted to encourage the use of alternative forms of energy (Smith 2010, Jacobson et al 2006, Huacuz 2005). This research will examine the emerging use of one alternative energy technology, solar water heaters, in an urban setting in southern Mexico. The study will consider a range of factors related to the overall adoption and diffusion processes such as perceptions of the technology, policy and regulatory frameworks, the competitive landscape, economic conditions, and how all of these factors interact to create the context in which the emerging technology operates.

While there have certainly been concerted efforts aimed at fostering "greener" technologies, serious concerns remain about the underlying assumption that new

technologies alone can resolve any of today's global environmental problems. Nonetheless, it is a fact that solar water heaters (SWHs) are rapidly emerging throughout the urban environment of Oaxaca de Juárez, Mexico (Oaxaca). This thesis will examine the complex processes of social and technological change as solar water heaters begin to compete with more conventional methods of water heating in Oaxaca.

Currently, the majority of households in Oaxaca rely on liquid petroleum gas (Gas LP) based systems for domestic water heating purposes. Recent policy initiatives at the national level, however, are seeking to encourage a large-scale transition to solar water heating systems. The most important policy, *The Program to Promote the Use of Solar Water Heaters in Mexico (*known as Procalsol for the Spanish acronym for *Programa para la Promoción de Calentadores Solares*), was established in 2007 and has begun to generate rapid growth in the use of solar water heaters in the residential sector across the country. Over the past 3 years, about 120,000 of these devices have been installed on the rooftops of homes across the country because of this policy and related programs (Infonavit and GIZ 2011).

As households begin to use these solar water heaters for the first time, people are forming a range of perceptions about the technology and actually experiencing these water heaters in very different ways. These different experiences and perceptions reflect the complex processes that have ultimately led to the installation of SWHs on the rooftops of thousands of homes in Oaxaca. By analyzing the course of diffusion as a messy and complex process, involving political institutions, competitive markets, materials, logistical networks, regulatory frameworks, skilled labor and more, we may be

able to better understand why end users have different perceptions of this emerging technology.

TECHNOLOGY AND SOCIETY

This research project is an examination of the process of technological change; how a society may transition from one form of technological system to another. This is a process that has occurred time and again throughout history, yet remains an incredibly difficult process to fully comprehend and describe. Often, new technologies appear to simply emerge from the great scientific or industrial unknown, become widely adopted by society, and sooner or later fade into the background of everyday life. Yet a closer examination of this process often reveals the wide range of relationships, struggles and negotiations that ultimately lead to a new system of technology.

Scholars have studied the phenomena related to changing technologies from a range of perspectives and developed a variety of ideas that seek to explain the relationship between a society and the technologies it employs. This is not an easy relationship to understand, and it is easy to think in ways that overemphasize the ability of one (either technology or society) to influence the other. For example, it is very easy to discuss technology as the primary driver of change within a society; to say, "any technology gradually creates a new human environment" (McLuhan 1964). Technology is thus seen as an exogenous force that creates changes in society. However, this line of thinking, labeled "technological determinism" tends to overemphasize technology's role in determining how society functions, while downplaying factors such as the political, economic, and social contexts in which a technology operates. Deterministic approaches

to understanding technology's role in society also tend to rely on the assumption that technologies develop based on an intrinsic logic, progressing linearly from less to more advanced configurations (Feenberg 2010). Historical studies of technology, however, indicate that there is generally more than one viable alternative to a given technological problem (Bijker 1995), and that the ultimate solution is based more on how the problem is defined, and by whom, than on purely functional concerns (Feenberg 2010).

Today, scholars from a number of backgrounds are developing new conceptualizations of the relationship between society and technology. One key understanding from all of these backgrounds is that technology and society are essentially inseparable. It is simply impossible to understand how a society functions without understanding the technologies that are embedded within that society, and similarly, it is impossible to fully understand any technology without accounting for the society in which it operates. Thomas Hughes describes this relationship between society and technology as a "seamless web" where the network of relationships between conceptions of what is "social" and what is "technical" become so enmeshed and tangled as to become truly inseparable as distinct ontological categories (Hughes 1983). Bruno Latour has echoed this sentiment in his description of technology as "society made durable." He says that "…any division we make between society on the one hand, and scientific or technical content on the other is necessarily arbitrary" (Latour 2000). This outlook is supported by scholars from a wide range of backgrounds and has led to the conceptualization of the relationship between technology and society as a "socio-technical" system.

In this vein, many scholars describe changes in the socio-technical system as processes of *co-construction* and *co-evolution*, where neither society nor technology alone is used to explain the other (Feenberg 2010, Coutard et al 2005, Misa 2003 p. 10, Geels 2002). Coutard et al succinctly explain how "technologies are shaped by society at the same time as they shape society or, in other words that (social) technical systems and (technical) societies co-evolve" (Coutard et al 2005 p 1) . These fundamental ideas, that society and technology are essentially impossible to isolate from one another, and that they change through co-evolutionary processes, will form an important foundation for my conception of the events taking place with solar water heaters in Oaxaca.

THEORETICAL BACKGROUNDS

In order to better conceptualize this relationship between technology and society, and how a place may transition from one form of technology to another, I have drawn from several established strands of literature. Each strand has been helpful for analyzing different components of this process. Specifically I will discuss ideas from the Diffusion of Innovation Theory, Social Construction of Technology, Actor Network Theory, and Ecological Modernization. I believe all of these theoretical backgrounds are useful for understanding the emergence of solar water heaters in Oaxaca. While aspects of each of these theories may be inherently incompatible with ideas of one or more of the others, there are many common themes, and strengths of one theory may be used to elaborate on weaknesses of another.

Diffusion of Innovations

This strand of literature focuses on the processes by which innovations become (or fail to become) widely adopted across a population. Some of the earliest contributions to this field of study come from the early French sociologist Gabriel Tarde in his 1903 book The Laws of Imitation. Everett Rogers points out how Tarde's use of the term "imitation" "implies that an individual learns about an innovation by copying someone else's adoption of the innovation, implying that diffusion is a social process of interpersonal communications networks" (Rogers 2003). In this book, Tarde famously described how the rate of adoption of a new idea or technology usually follows an "S" shaped (logit) curve over time (Tarde 1903). Relatively little scholarly work was published on the topic of diffusion processes until a pioneering study on the diffusion of hybrid corn in two communities in rural Iowa was undertaken by Bryce Ryan and Neal Gross in the late 1930s. This groundbreaking work examined farmers' decisions concerning whether or not to adopt high-yielding hybrid corn varieties. This study reinforced the notion of an "S" shaped adopter curve, while yielding new insights about the range of decisions made as potential adopters moved from gaining knowledge of the innovation toward ultimate adoption (Ryan and Gross 1943). Hailing from a similar background in rural sociology, Everett Rogers worked to more fully develop diffusion of innovation theory, and with his seminal work, Diffusion of Innovations, is regarded as the most influential scholar in the field of innovation studies.

Rogers defines diffusion as "the process in which an innovation is communicated through certain channels over time among the members of a social system" (Rogers 2003, p5). The four elements of this definition (innovation, communication channels, time and a social system) are understood as four essential elements present in any diffusion process. This definition of diffusion stresses the importance of communication (most

importantly peer-to-peer communication) as a central component of the diffusion process (Rogers 2003, p18). Rogers also formulated many central ideas of diffusion studies such as the categorization of adopters based on the time of adoption (early adopter, early majority, late majority, laggard), the stages in the innovation decision process (knowledge, persuasion, decision, implementation), and the attributes of specific innovations that affect adoption rates (relative advantage, compatibility, complexity, triability, observability).

Geographers have also made significant contributions to diffusion of innovation studies, with significant research on the topic through the 1960s and 70s often consisting of quantitative models for describing the spread of an innovation through space. Torsten Hägerstrand was probably the earliest scholar to discuss the diffusion process from an explicitly spatial perspective, developing his ideas in the aptly titled 1967 book Innovation Diffusion as a Spatial Process. His model examined the spatial aspects of diffusion, emphasizing the importance of the spread of information through networks of social communications whereby an innovation spreads from a few innovators to the general public (Hägerstrand 1967). This mostly quantitative model of diffusion processes was later criticized for relying too heavily on spatial proximity to account for the spread of information, while discounting differences in real human relationships (Blaut 1977), and also for failing to account for circumstances when a propagator has an interest in the rapid and complete diffusion of an innovation (Brown 1975).

In addition to examining underlying processes of diffusion, geographers have also explored the effects of diffusion processes on different populations. Geographer

Lakshman Yapa, taking a more critical approach to diffusion studies, described a diffusion model based on the spread of agricultural techniques associated with the "green revolution" in India. Diffusion processes were shown to potentially have unintended macro-level socio-economic impacts, possibly exacerbating inequalities, especially in the third world context (Yapa 1977).

The literature on diffusion of innovation has developed keen insights into the nature of how specific innovations become, or fail to become, widely adopted and tend to move through space. This study on the diffusion of solar water heaters in Oaxaca will contribute to the empirical record concerning how this technology is beginning to diffuse throughout the city.

Social Construction of Technology

One perspective for understanding the diverse range of factors that support a given technology is through the lens of the social construction of technology (SCOT) (Bijker et al. 1989, Douglas 1987). In this conceptualization, technologies are seen not as simple physical artifacts that perform specific tasks, but rather as products of a wide range of social contexts and the ways in which social groups understand and choose to employ the technology (Bijker 1995, Callon 1987). Bijker explains that

> a central adage for this research is that one should never take the meaning of a technical artifact or technological system as residing in the technology itself. Instead, one must study how technologies are shaped and acquire their meanings in the heterogeneity of social interactions (Bijker1995, p 6)

Thus, as technologies emerge, uncertainties concerning their function and form are answered and interpreted differently by different groups of people (interpretive

flexibility). As these groups of people interact, they gradually develop shared meanings of the technology, ultimately arriving at some dominant design (closure).

Susan Douglas' study of early radio history effectively uses this approach to analyze how "individuals, institutions, ideas, and technology interacted to produce radio broadcasting" (Douglas 1987). Wiebe Bijker similarly shows how as early bicycles were being developed, they went through a variety of transformations, responding to different social contexts and sets of demands (Bijker 1995). For example, one early form of the bicycle, the "Ordinary" bike, with its extraordinarily large front wheel, was generally considered both difficult and dangerous to ride. For many people, the Ordinary bike was therefore defined as an "*Unsafe Bike*". However, for a group of mainly young, upper-class men, this *Unsafe Bike* gave them a chance to show off in front of young women in London parks. For them, the Ordinary bike was not the *Unsafe Bike*, but the *Macho Bike*. In this vein of thinking, technological artifacts contain no meaning in and of themselves, but derive meaning from the social context in which they operate (Bijker 1995). In the case of solar waters heaters in Oaxaca, there is also evidence that different people and groups of people, based on their own experiences, have attached different meanings to this technological artifact. For some people living with solar water heaters, they may be defined as an ecologically friendly tool for saving money on fuel each month, while for others they may be viewed as an expensive piece of metal on the roof that never quite works; some people see the heaters as a simple device to store hot water already heated

from a gas boiler, while others may view it as a potential competitor to an existing business model.

Another key concept from the SCOT school is the idea that technologies develop or "evolve" in ways that are analogous to the processes of biological evolution (Pinch and Bijker 1984). Ideas and technology build upon earlier ones, and based on processes of "variation and selection", a new form of technology ultimately emerges. This evolutionary model of technological change is based on ideas from evolutionary economics and has been applied in several other theories of technological change, including the multi-level perspective (Geels 2002).

Under this model, versions that appear to be aberrations from a historical perspective should be examined as serious contenders for becoming the actual accepted form of the technology. By analyzing why these "aberrations" were not selected, we can learn about the factors that led to the development of the winning form. The terms "winning" or "accepted" form, however, do not imply that a given technology will not undergo additional changes due to social or technical pressures; any "winning" form is itself a temporary stabilization of forces that is always susceptible to additional transformations. In this study, we will see how the form of solar water heaters in Oaxaca is currently being negotiated between two competing versions (glass and copper) of the technology.

Other important concepts from the social constructivist school include the ideas of "closure" and "stabilization" which attempt to describe the processes by which conflicts surrounding technological artifacts are negotiated and ultimately resolved so that a

generally accepted form does not (or is not perceived to) pose a problem to any relevant social group (Klein and Kleinman 2010). The concept of "relevant social groups" itself comprises a final key concept of the SCOT school, and is used as a method for categorizing groups of parties involved in the social construction of a technology. The main requirement defining a relevant social group is that all members "share the same set of meanings, attached to a specific artifact" (Pinch and Bijker 1984). This concept of relative social groups, however, has been a central part of the critique against SCOT for implicitly assuming that all relevant social groups are equal and present during the design process (Klein and Kleinman 2010). An approach is required that recognizes different stakeholders with unequal levels of power during the development and diffusion processes of a technology. It is my goal to analyze the interactions between disparate groups with vastly different levels of access to power and resources as equally essential components of the overall process.

Actor Network Theory

"Hence the term actor-network- an actor is also, always, a network." (Law 1992)

The opening paragraph of this text mentioned some recent catastrophic technological failures. Nuclear meltdowns and massive oil spills clearly raise questions and call for investigations, but also, in many ways, provide an opportunity to think about all of the complicated aspects that allow these technologies to normally run so smoothly. If a light bulb suddenly stops emitting light after the first two hours of use, we may try to isolate just what went wrong in this seemingly simple device. How many factors and

variables have to function in harmony for one light bulb to emit light? We may begin to think about this object as a product of the variety of component parts that make it up (and inquire into which part is creating the problem…). However, a light bulb is comprised of more than just the "component parts"; it is also a product of applied scientific knowledge, government regulations, certain laws of physics, transportation systems, as well as a number of other factors. Quickly, then this light bulb is broken down into a far reaching network that has somehow stabilized all together to form what we know as a single object- a light bulb.

In everyday speech, we have no problem conceptualizing and speaking about a single device called a light bulb without acknowledging the vast network of supporting characters. In fact it would be impossible to communicate without making these types of conceptual simplifications. When we say "light bulb", the physical artifact of a light bulb pops into our mind, and that single object symbolizes and simplifies all of the things (glass, filament, factory workers, and electrons) that actually make it so. When a defect is found, however, it is normally difficult to immediately know where the source of the problem originated. Was it an issue of factory oversight, a regulatory loophole, mishandling upon delivery, or an outside event such as a power surge? These defects and malfunctions, then, often provide us with the opportunity to think about the wide-ranging network of actors that stabilize together to support a given technology. Actor-network theory, or the sociology of translation (Callon 1986), then is an attempt to understand all phenomena as effects of patterns of relationships between heterogeneous materials (Law 1992); the goal is not to list the parts or ideas that make up some "thing", but to describe

the relationships between those parts (etc…) as stable (or not) enough to justify that that "thing" actually exists. These relationships often appear to be stable, and become *translated* (and simplified or *punctualized)* into words that imply a single point actor (Law 1992). As John Law has noted, this is how we can talk about "'The British Government' rather than all the bits and pieces that make it up" (Law 1992).

From this basic understanding that any technology is really the product of a wide ranging network of heterogeneous (-both social and technical, human and non-human) parts, we can better understand how, in fact, anything can be analyzed in terms of being a network; materials, ideas, and even humans themselves. Sociologist John Law explains how

> people are who they are because they are a patterned network of heterogeneous materials. If you took away my computer, my colleagues, my office, my books, my desk, my telephone I wouldn't be a sociologist writing papers, delivering lectures, and producing "knowledge." I'd be something quite other--and the same is true for all of us.

So , ANT in this way refuses to make distinctions between spheres of the social or the technical, because, in most cases there is no such thing as anything purely one or the other--a light bulb is not purely "technical" and a human is not purely "social."

By refusing to distinguish between the social and the technical as separate ontological categories, ANT expands the frame of reference so that actor-networks can consist of both human and nonhuman actors (Callon 1986). This research project is an attempt to glimpse into the network of actors supporting SWHs in Oaxaca, where they are still in a relatively formative stage and stabilizations form and dissipate more rapidly

than they may with a firmly established technology. In analyzing the emerging use of solar water heaters in Oaxaca, I have found this to be a highly useful tool for conceptualizing the broadest possible network of actors that are allowing this phenomenon to take place. Through this perspective we can see how policy makers, international aid groups, homeowners, and the International Copper Association are all important reasons why people are now living with these novel systems on their roofs.

The Multi-level Perspective

Building upon these general ideas of technology and society, the Multi-Level Perspective is essentially an analytical model for conceptualizing the processes involved as a society transitions from one technological system to another. This perspective utilizes the term "transition" to denote "major technological transformations in the way societal functions are fulfilled" (Geels 2002, p 1257). The major thrust of the MLP is to conceptualize and describe how these "socio-technical transitions" occur.

This model (Fig. 1) has emerged over the last decade as a number of scholars in the field of Science Technology and Society have analyzed historical cases of technological change to develop a general framework for how this infinitely complex process of a socio-technical transition may take place (Rip and Kemp 1998, Geels 2002, Smith et al 2005, Genus and Coles 2008). In short, the Multi-Level Perspective describes socio-technical transitions as occurring through an alignment and series of interactions between three analytical levels: the landscape context, the socio-technical regime and the niche technology (Geels 2002). Each of these analytical levels is in turn composed of a broad network of heterogeneous actors, linked together to provide varying degrees of

structure and stability for each respective level (Geels 2002). It is the interactions between these three levels, then, which creates the conditions necessary for a socio-technical transition to occur (Geels and Schot 2007). These three levels will be briefly described to give a better understanding of this conceptual model.

Socio-technical regimes consist of the dominant socio-technical system in place, encompassing the broad spectrum of heterogeneous components involved in the status quo socio-technical system. This includes entities such as the financial networks, suppliers, consumers, producer networks, research networks, material components, and public authorities that together support a given socio-technical system (Rip and Kemp 1998, Geels 2002). Kemp et al have defined a technological regime as "the whole complex of scientific knowledges, engineering practices, production process technologies, product characteristics, skills and procedures, and institutions and infrastructures that make up the totality of a technology" (Kemp et al 2000). A key component of socio-technical regimes is that they are understood to be relatively stable, and tend to guide technological changes along incremental, as opposed to radical, trajectories (Geels and Schot 2007). In the context of water heating in Oaxaca, the regime level socio-technical system can be described as the current gas-based system of water heating.

Technological niches are perhaps best described as 'incubation rooms' for nascent technologies that seek to transform the dominant socio-technical regime, but have not yet been able to break through to overtake the dominant regime (Schot 1998). Niches often develop in settings not governed solely by traditional market rationalities such as within an ideological social group ("green consumers"), or within a more formal institution such

as the Army (Geels 2002). In this sense, niches are protected from normal market conditions, and provide opportunities for learning and the development of social networks which support innovative technologies (Geels 2002). The relationships and general structure of the niche level are often unstable and susceptible to rapid changes (Geels and Schot 2007).

Unlike the niche or regime levels, which essentially describe market maturity of specific technologies, the landscape level describes the over-arching, and relatively stable, *context* in which regimes and niches operate (Geels 2002). These may include a wide range of heterogeneous factors such as climatic conditions, political systems, macro-economic conditions, cultural values, demographic conditions, and other macro level circumstances (Geels 2002, Geels and Schot 2007, Smith 2010). The landscape level is inherently stable, with change usually taking place over the long term (decades) (Geels and Schot2007).

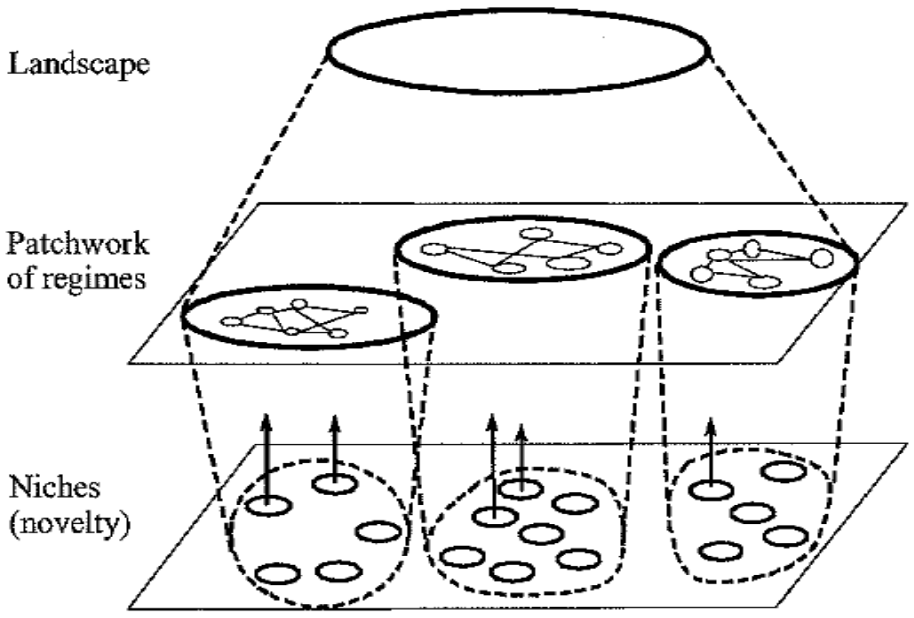

Figure 1: A model of three levels of the multi-level perspective (Geels 2002)

These three dynamic levels (niche, regime, and landscape) interact and affect each other in various ways. For example, significant changes at the landscape scale may cause the structure of the dominant regime to "loosen", providing an opportunity for niche-level innovations to compete in the open market (Geels and Schot 2007). Similarly, niches may be at different stages of development when opportunities open up in the regime, affecting the ability for niche opportunities to respond to these opportunities. Socio-technical transitions are able to occur when the three levels align together in ways receptive to change. Depending on the timing and nature of the multi-level interactions, a number of "transition pathways" have been described whereby niches can break through to the regime level (Geels and Schot 2007).

Based on concepts developed in the field of Evolutionary Economics and previously applied in SCOT (Pinch and Bijker 1984: 411), the MLP conceives of socio-technical transformations as an essentially evolutionary process whereby technological configurations undergo process of variation and selection (Geels and Schot 2010).

One recent strand of the research utilizing the multi-level perspective to analyze socio-technical transitions has focused on the change towards more environmentally benign economic and technological systems (Cohen 2010, Köhler et al 2010, Lauridsen and Jørgenson 2010, van Bree et al 2010). An important, though seemingly obvious finding, is that transitions towards sustainability face a number of challenges and barriers that may take years or decades to overcome (Geels 2010). Strong structural components of the current fossil-fuel based system (sunk investments, behavioral patterns, vested interests, infrastructure, regulations, and subsidies) compose a mechanism of "carbon lock-in" strongly reinforcing the current socio-technical regime (Unreh 2000, Geels 2010). While recognizing this fact, recent research has used a variety of case studies and comparative analyses to evaluate the possibility of modern transitions to more sustainable systems such as transportation (Kohler et al 2009), food (Smith 2006), and waste management (Lauridson and Jørgenson 2010).

One recent critique of the body of literature surrounding the MLP pointed out a general lack of geographical perspective in the existing research (Coenen et al 2011, Smith et al 2010). According to Smith et al, "The role of places and spatial scales in these transition processes has not been an explicit issue of concern… research is only beginning to explore how this geography influences transitions" (Smith et al 2010).

Coenen et al (2010) have pointed out that the levels of regime or niche carry no spatial connotation and merely refer to the level of maturity of the technological system, while the landscape level is merely an exogenous background in which the technologies compete which similarly is devoid of any explicit spatial scale. They argue that any analysis of a transition must also recognize that the interactions between these three *analytical levels* are also happening, simultaneously, on different *spatial scales*, from the local to the global. They define a geographical scale as

> a level at which significant relationships exist between actors: these relationships acquire a dynamic of their own through repeated interaction and that dynamic is distinctive from interactions at different scales (Coenen et al 2011).

This study will investigate this multi-scalar aspect of transitions in the case of Oaxaca, where local regional, national, and international actors have interacted and played important roles in creating the necessary context to allow for the emergence of solar water heaters.

In addition to a general lack of research regarding the role of place, an additional gap in the literature has been identified relating to any explicit focus on the urban context (Späth and Rohracher 2010, Hodson and Marvin 2010). Hodson and Marvin have pointed out that:

> Transitions approaches have been somewhat limited in focusing on spatial scales aside from the national level. In particular, transitions approaches have said little about cities and what the multi-level perspective on systemic transitions can contribute to understanding urban socio-technical transitions…Further research should engage with transitions in cities outside of premium world cities and examine what transitions look like in ordinary cities and cities of the global south (Hodson and Marvin 2010).

This study will address these gaps in the literature and add to the empirical accounts of processes related to socio-technical transitions in a non-"premium world city" in the global south.

Ecological Modernization

While these different theories provide insightful means of analyzing the relationship between society and technology and conceptualizing how technological transformations may occur, we are still left with basic questions concerning the utility of "green technologies" for solving global environmental problems. Many people may find themselves asking, "Can new technologies really solve resolve global environmental problems or are they just contributing to the traditional patterns of production and consumption?" "Can a market-based economic perspective co-exist with an ecological perspective?" And, grounded in a sense of the interdependence of social and technological change, "to what extent can new technologies account for both economic and ecological well-being?"

Ecological Modernization Theory is an attempt to better understand this relationship between ecological and economic rationalities. Taking a relatively optimistic perspective, the theory describes how "industrial societies might adapt to fit within the earth's carrying capacity using better scientific knowledge, technical progress, economic growth and democratic decision making" (Coenen et al 2011). The term 'ecological modernization', coined in the early 1980's, is an attempt to conceptualize the role of technology in bridging economic and ecological functions (Cohen 2006, Huber 2008, Jänicke 2008). Jänicke explains how "The intention was to link the drive for

modernization in the developed market economies and the long-term requirement for an ex-ante more environmentally friendly development through innovation in environmental technologies" (Jänicke 2008). One idea stemming from this perspective is that there is a growing autonomous ecological rationality that is challenging the dominant economic rationality so that "economic processes of production and consumption are increasingly analyzed and judged, as well as designed and organized from both an economic *and* an ecological point of view" (Mol 2002 p 93).

Jänicke similarly describes the importance of technologies that can be mutually beneficial to both the economy and the environment: "The emphasis of this approach lies on the possibility of ecological-economic 'win-win' solutions that can be achieved, above all, through cost reduction and competition for innovation" (Jänicke 2008).

This generally sanguine outlook on the role of technology for mediating between economic well-being and environmental concerns has been heavily criticized from many perspectives. Many in the North American environmental movement, for example, have criticized EM for overselling the benefits, while underestimating the costs, of visionary technological solutions to environmental problems (Cohen 2006). York and Rosa (2003) argue that EMT has at least four substantial logical or methodological contradictions: 1) It has not differentiated between environmental policies or claims and actual environmental achievements; 2) It has overly relied on case studies which may not be generalizable across all phenomena; 3) It has not accounted for spillover effects such as when ecological improvements in one sector may come at the expense of increased ecological impacts in another; 4) It does not accounted for the possibility that increased

efficiency is not sufficient to lower total levels of production and consumption (Jevon's paradox).

Ecological Modernization, then is a helpful framework for understanding the role technology may play in future attempts to limit human activity to levels consistent with the carrying capacity of the earth. While this theory takes a generally optimistic perspective regarding the future role of technology, this is clearly a contested stance, with many valid criticisms. Overall, I have found this to be a useful set of ideas for understanding the motivations and goals surrounding the promotion of solar water heaters in Oaxaca.

Vincent Mosco has argued that technologies often arrive with a mythical sense of opportunity and ability to fundamentally alter the world. In a similar vein, Howard Segal argues that "technological utopianism" has existed for centuries and plays an important role in the development of a society[1]. While new innovations often inspire grand thoughts about the future, they also tend to have the most social impact as they become banal and nearly unnoticed (Mosco 2005). Alternative energy technologies are often imbued with this sort of mythical ability to transform the way we power our world. By critically examining the processes involved in the emergence of solar water heaters in Oaxaca, I hope to gain some insights into the nature of the wide range of factors involved in these processes, and how they all may be impacting the city of Oaxaca.

[1] Segal primarily focuses on the role of technological utopianist thinking in the development of American socity

Chapter 2: Location and Methodology

OAXACA

"Highly stratified inequality, cycles of economic expansion and contraction, and struggles between local and national interests – all of which are reflected in the landscape, monuments, and handicrafts – have characterized Oaxaca for millennia. They are rooted in the environment and the history of the region" (Murphy and Stepick 1991 p 8).

Oaxaca de Juárez is the capital city of the mountainous state of Oaxaca in southern Mexico. Situated in a valley surrounded by towering mountain ranges, Oaxaca is a rapidly growing city of about 265,000 people located in the heart of a largely rural and indigenous state (Inegi.org) (Fig. 2). The city lies at an elevation of about 1,555meters (5,102 feet) with a dry-temperate climate comprised of dry winters and rainy summers. On the surface, Oaxaca maintains a tranquil pace of life set to the backdrop of cobble stone streets and impressive colonial architecture that dates back to the early 16th century (Fig. 3). In fact, urban settlement in the area dates back much further; the city sits directly in the shadows of the ancient Zapotec hilltop city of Monte Alban, founded around 500 BC. Over the next roughly 2,000 years, the region was ruled by competing Zapotec and Mixtec dynasties. Throughout the broader region of the present day state, indigenous Chinantecos, Mixes, Mazatecos and several other groups were also establishing settlements and cultures in the area.

Figure 2: Map of Oaxaca State (Maps of Mexico 2011)

The Spanish arrived in 1521 Oaxaca, shortly after conquering the Aztec capital of Tenochtitlan, beginning the era of colonial rule in Oaxaca. By 1750 Oaxaca, then known as Antequera, had a population of about 18,000 and served as an administrative and commercial center for the surrounding rural areas (Guardino 2005). Although there was gold throughout the region, Oaxaca became a chief exporter of Cochineal, the red dye extracted from the small insect the *grana cochinilla*, leading to great wealth for a few

elite families who dominated the city.

Figure 3: A cloudy day in the Central Historic District of Oaxaca

Despite centuries of colonial rule, the indigenous communities throughout the state of Oaxaca have been able to maintain much of their cultural and linguistic tradition. According to the National Institute for Geography and Statistics (INEGI), about 34% of the current population in the state of Oaxaca speaks an indigenous language[2] (cuentame.inegi.org). Cultural events and festivals, such as the annual Guelaguetza, and smaller events throughout the city highlight Oaxaca's ties to the indigenous cultures found throughout the region.

[2] INEGI also reports that 14% of indigenous language speakers in Oaxaca State do not speak Spanish

Although the area has been home to urban settlements for over 2,500 years, the city and its citizens continue to face a range of pervasive and systemic problems. Poverty, unemployment, lack of access to basic municipal services, and political corruption are an ever present backdrop to life in Oaxaca. These significant problems result in frequent protests, marches, and blockades throughout the city (Fig. 4).

Urban Anthropologists Murphy and Stepick explain the social context of Oaxaca City in their 1991 book Social Inequality in Oaxaca: "While primarily nonlocal elite continues to prosper, just as at the end of the nineteenth century reforms and the twentieth century revolution, the majority of Oaxacans protest and struggle against the city's growing inequality" (Murphy and Stepick 1991, p xiii). At times these simmering problems reach a boiling point, and large demonstrations, strikes, and protests are a relatively frequent part of Oaxaca life.

In the book "Social Inequality in Oaxaca" Stepick and Murphy explain that they "focus on social inequality because it has characterized the region's society for more than two millennia and we believe that in one form or another it is one of the most fundamental problems that its inhabitants face daily." During my own research and time spent living in the city of Oaxaca, I have come to agree with this statement. They define social inequality as "differential access to and possession of material goods, that is material hierarchal stratification" (Stepick and Murphy). Using this definition, I will attempt to examine how the promotion and subsidizing of solar water heaters may be affecting social inequality in Oaxaca City.

Figure 4: Political protest in Oaxaca

METHODOLOGY

The overall aim of this project is to describe a place, in a specific moment in history, as a new technological artifact is beginning to emerge. The methodology I have employed has been informed by the objectives of the various strands of literature I have drawn from. This study is essentially an attempt to take a "panorama photo" of this time and place to better understand how a technology emerges in a place and a society. In this way, I am at times following the advice of Bruno Latour, who advises social scientists to avoid any a priori attempt at fitting a given situation into a specific framework and instead to "just describe the state of affairs at hand" (Latour 2005, p 144). However, this

is not always as simple as it sounds, and it takes careful observations and interactions with the events taking place on the ground to be able to describe a given situation, without interfering with it.

Field work for this project was conducted in Oaxaca, Mexico during the summer of 2010. My goal has been to allow my experiences and observations to tell their own story and my methodology was an attempt to reflect that spirit. I began by drawing on methodological advice from Wiebe Bijker who describes two steps in identifying "relevant social groups" in a socio-technical system: "roll a snowball" and "follow the actors". These techniques refer to the use of previously identified actors to identify additional components of the network, and the recommendation to allow the actors themselves to define the categories of actors as they perceive them. To begin, Bijker suggests drawing on previous knowledge of the situation and common sense to identify people or groups who are clearly relevant to the issue at hand.

Having lived in this area for nearly two years, and reading extensively on much of the above literature, I identified a number of individuals and institutions involved in solar water heating activities in Oaxaca who I felt would be helpful to speak with. During or following each of these initial interviews, I asked the interviewees about who else I should speak with. As Bijker explains, by asking actors to identify others, "the number of new actors at first increases rapidly, like a snowball, but after some time no new names will be mentioned- you have the complete set of actors involved in the controversy" (1995 p 46). I will add to this statement that I believe it is probably impossible to truly identify the "complete set of actors" involved in a situation, especially when each actor

itself is considered as a network comprised of other actors (who/which are also networks ad infinitum..). However, this method is helpful for gaining a basic understanding of some of the relevant social groups.

Bijker also encourages researchers to "follow the actors" and allow the actors themselves to define and describe what they perceive as being the relevant social groups. This issue of boundaries and defining what constitutes a "group" or an "actor" is probably the trickiest part of operationalizing the conceptual ideas (especially from ANT) that form the general framework for this study. Bijker realizes this difficulty and describes how actors simplify their world, and the practical method of describing the situation is just to follow what they say themselves.

> "In the turmoil of technical development, actors, to make sense of their world, will identify new relevant social groups or forget about others. Thus, the boundaries of social groups, although once clear cut, may become fuzzy; new groups may split off and old groups may merge into new ones. Actors thus "simplify" and reorder their world by forgetting about obsolete distinctions or by drawing new boundaries" (Bijker 1995 p 48).

With this in mind, I made a genuine attempt to allow the actors to speak for themselves. In the end, however, my analysis of the situation surely reflects some of my own perspectives and biases.

During the course of my research, I was able to interview new homeowners with SWHs, architects, engineers, policymakers, the president of a prominent gas company, store managers, residents of nearly 30 neighborhoods, SWH installation professionals and many more. My focus concerned how these groups interacted with each-other, with their

broader political, economic, or cultural contexts, and with technical aspects of the technology.

Interviews were conducted among ten households in each of two subdivisions where solar water heaters had recently been installed. These interviews focused primarily on how the respondents thought of the solar water heaters and how these perceptions may have changed after living with one. Some questions tended to be answered in a binary fashion, whereby responses could generally be coded "yes" or "no" (such as whether the respondent was fully informed and understands the function of the heater) whereas other sets of answers were clearly more open-ended (such as the value placed on hot water). The delineations between categories were not preconceived or suggested, but only emerged after reviewing the data in aggregate. When specific cases are presented, they were selected to highlight central themes found in each of these subdivisions.

Shorter surveys and interviews were conducted with sixty residents of Oaxaca City on excursions to various neighborhoods within the city. These respondents were chosen at random, although a conscious attempt was made to gather data from residents from a diverse range of neighborhoods (29 distinct neighborhoods are represented). This was accomplished by travelling throughout the city and conducting a small number of surveys in a variety of neighborhoods.

While there has been significant work analyzing how processes of socio-technical change may have occurred in the past, there is much less empirical work that has attempted to analyze a socio-technical transition that is currently underway. This is not

an accident. It is inherently difficult to describe an ongoing socio-technical transition for many reasons, the strongest of which are that A) it is impossible to know if any newly emerging technology will actually transition into a dominant technology in the future, and B) large scale socio-technical transition processes often occur in the time frame of decades. My research is an attempt to gain a better understanding of the early stages of a possible sociotechnical transition towards the use of solar water heating technology in the present context.

Another important point when trying to conceptualize a certain technology's relationship to society involves the notion of defining the geographical scale of the study and its relationship with space. This idea of the fusion of space/place with technology, termed 'technicity', takes an explicit interest in the geographical context in which technological change takes place (Adams 2007).

Overall, Oaxaca is an intriguing place to study the emergence of this technology. Oaxaca is a rapidly growing city, simultaneously seeking to create economic opportunities and improve the quality of life its residents through technology and modernization, while also maintaining its strong sense of place and unique heritage. These changes are all taking place amid a tense political climate where struggles for power often overflow into the streets and public spaces throughout the city. In order to best capture the processes related to the emerging use of solar water heaters, I have tried as much as possible to let the people of Oaxaca speak for themselves. While I am no doubt writing based on my own perspective and biases, my goal is to simply relate the story as I have seen and heard it.

In the following chapters, I will attempt to describe and analyze the process of the emergence of solar water heaters throughout the urban landscape of Oaxaca. While I have provided a brief account of Oaxaca, I hope to illuminate more about this fascinating place through the account of the emerging use of this technology.

Chapter 3: Oaxaca and Everyday Experiences with Hot Water

In order to gain a better understanding of the processes involved in the emerging use of any new technology, it is clearly helpful to first examine the main system of technology currently being employed. With this in mind, before examining solar water heaters in Oaxaca Mexico, I would like to describe the present conditions of domestic water heating in Oaxaca. Oaxacans currently heat their domestic water in many different ways and have a wide range of values and perceptions concerning hot water in general. The solar water heaters that are currently being installed throughout the city are ostensibly designed to solve some type of problem with the current water heating system, yet it appears that the problem that they are designed to solve is not the same for everyone. There are different interpretations and ideas concerning the very nature of domestic hot water complicating the reasons why different people would even be interested in the technology. As Andrew Feenberg has written, "what a technology *is* depends on what a technology is *for,* and that is often in dispute" (Feenberg 2010).

This chapter will examine citizens' values related to hot water use in general in Oaxaca and explore the current systems used for water heating in Oaxaca. Two key findings in this chapter are relevant to understanding the emerging use of solar water heating technology. First of all, there are a diverse range of views and opinions regarding the value of water heating by households in Oaxaca City. It would be a mistake to assume any homogenous or universal values concerning hot water use in Oaxaca, and therefore to discuss residential users in general as a monolithic group. Solar heaters,

then, should be analyzed with the understanding that there are a wide variety of opinions concerning the importance of hot water in general. Each individual creates their own relationship and perception on the technology. As the process of diffusion of innovations is a social process, highly dependent on peer-to-peer communication about the innovation, differing perceptions can ultimately affect the overall social acceptance and rates of adoption of an innovation.

Second of all, there are direct interactions between households using solar water heaters and those that are not. By analyzing how people are currently heating water, we can get a better idea of the changes that may be taking place in the current system of water heating and better understand the relationship between the current systems and the emerging solar water heating niche. In this sense, one goal of this section is to begin to explore the interactions between the current (mainly) gas based water heating regime and the emerging green niche of solar water heating. Adrian Smith has done extensive research on the interactions between emerging green technologies and dominant socio-technical regimes in areas such as organic food and eco-housing. He describes how "green niches are constructed in opposition to incumbent regimes. They are informed, initiated and designed in response to sustainability problems perceived in the regime" (Smith 2007 p 436). This chapter will describe the make-up of the current gas based regime, laying the groundwork for an exploration of how its interactions between this dominant system is affecting the emerging use of solar water heaters in the area.

CURRENT SYSTEMS FOR WATER HEATING IN OAXACA

It is estimated that Mexico currently uses about 230 PJ of energy per year on low temperature (below 100˚C) water heating (Procalsol 2007). The residential sector accounts for the majority of this use, followed by the industrial and agricultural sectors. In total, the energy dedicated to low temperature hot water heating accounts for about 6% of national energy consumption (Ibid). Fossil fuels provide the main source of fuel for water heating, with liquid petroleum and natural gas being the two largest sources of this fuel. In total, it is estimated that the current methods of water heating emit approximately four million tons of carbon dioxide into the atmosphere each year (Ibid.). The use of these fuels also represents a significant expense for the users. The Secretary of Energy has estimated that Mexican consumers currently spend around $4 Billion USD a year in fuel costs for low temperature water heating (Ibid.).

Although hot water may not be as essential to everyday life as other services such as access to potable water or electricity, the large majority of Oaxacan households do use hot water for domestic purposes (especially for bathing). Oaxacan households currently heat their water in several different ways, with solar water heaters being a relatively uncommon method that is only beginning to emerge. Some methods that are used for residential water heating include gas boilers, stove tops, electricity and firewood. In my survey around the city, I found that just over half of the residents (31/60) I spoke with use a gas boiler to heat their water. One electrical engineer I spoke with estimated that around 90% of homes in Oaxaca have gas boilers. Although my research showed a smaller percentage, gas boiler water heating systems do appear to be the most common

system used in Oaxaca. The second most common water heating method is to heat a pot of water on the stove, mix it with cooler water in a larger bucket, and bathe with that warm mixture by pouring it over the body with a smaller cup or bowl. This method also relies on natural gas from the stove and accounted for slightly over 25% of respondents. In total 78.3% (47/60) of those surveyed indicated that they use gas based systems for at least part of the year to heat their water, illustrating the importance of gas for providing hot water for Oaxacan households.

GAS BASED WATER HEATING IN OAXACA

Like most of Mexico, Oaxaca is not equipped with the infrastructure to deliver gas to individual residences and businesses through subterranean pipes. Instead, gas is manually delivered to the consumers individually, as it is needed, by gas delivery trucks which are managed by one of four major gas companies that operate in Oaxaca. These gas trucks deliver gas in one of two different forms: in individual gas tanks (of 20, 30, or 45 kilograms), or by filling up larger stationary tanks that are situated on the roofs of some buildings (Fig 6).

As gas is used for either cooking and/or water heating by nearly everyone in the city, these gas trucks have plenty of deliveries to make. Most homes are not equipped with any type of sensor to indicate the level of gas remaining for the stove or the boiler, and so when the gas runs out it must be purchased before any cooking or water heating can resume. Luckily for the residents of many parts of Oaxaca, they usually don't have to wait very long for a gas truck to pass by. Their ubiquitous presence throughout the city is constant and unmistakable (Fig. 5). After a few days in the city limits, it is nearly

impossible not to be familiar with several of the jingles that blare out of the speakers of the slow moving gas trucks as they ramble up and down the streets of the city. "BBEEEEEPPP!!!! GAAAAS DE OAAXXXAACAAAA!!! GAAAASSS DE OAXXXAAACCAAA!!! KILOS EXACTOS!!! KILOS EXACTOS!!! GAAAS DE OAAXAAACA!!!" is one common refrain, brought to the city by the gas company, Gas de Oaxaca. Or the slightly more subtle jingle of several metal rings dangling from a metal chain dragging on the bumpy concrete behind the Milenium Gas trucks. Or the ever popular *Norteño Banda* song "Como me Duele" blaring from the Sonigas trucks. On a typical weekday in a relatively central neighborhood, a home or office may be passed by a dozen gas trucks. Their presence is an undeniable part of the urban environment (both visual and auditory) of Oaxaca.

Figure 5: Gas trucks pass each other on a bumpy street

As these gas trucks, and the entire system of LPG-fueled water heating technology makes up an important part of the current water heating regime in Oaxaca, it may be useful to more fully examine exactly how the current system functions. Through a personal interview with the president of one of the largest gas companies operating in Oaxaca, Sonigas, I was able to glean a more complete understanding of this system.

Currently, 4 companies provide LPG services for the state of Oaxaca: Gas de Oaxaca, Milenium Gas, Sonigas, and Sersi**.** These companies each have a central facility outside of the city of Oaxaca where trucks fill up with gas and drive into the city to make deliveries. Sonigas alone operates about 50 trucks in Oaxaca which typically load up first thing in the morning and operate in one of two general areas. The "primary" area includes Oaxaca City and about a 30 Kilometer radius, while the "secondary" market is between 30 and 60 KM from Oaxaca City and is serviced less frequently.

In some ways then, this infrastructure network of gas delivery may redefine the boundaries of the city itself. Just as boundaries between concepts of social and technical may be broken down upon analysis, Graham and Marvin argue for the dissolution of conceptual boundaries between the city and their related infrastructure networks

> We recognize rather, that much of the 'urban' is infrastructure; that most infrastructure actually constitutes the very physical and socio-technical fabric of cities and infrastructure are seamlessly coproduced, and co-evolve, together within contemporary society…we need to remember that infrastructures are thoroughly social constructions whilst cities are also infrastructural constructions" (Graham and Marvin 2001 p 179).

Through this perspective then, technologies such as solar water heaters, which function without a reliance on infrastructure for fuel delivery, may change some conceptions of what actually comprises the city.

While the jingles and noises of the trucks easily distinguish one gas company from another, there is no easy distinction when it comes to price or the actual product being delivered. The national market and price for LPG is determined by PEMEX (Petroléos Mexicanos) and the federal government and dictated to the gas companies, and the public, at the beginning of each month. By federal law, PEMEX is the one and only source of LPG available to any of the gas companies. Typically the price of gas rises slightly, recently by about 20 centavos/kilogram/month[3]. The gas companies therefore maintain a fairly close relationship with the federal government, a relationship described by the chief of one gas company as one between "partners."

And as with any relationship, there are pros and cons for the gas companies being so tightly tied to the federal government. The over-riding positive for the gas companies is that government cooperation is required for the permission to enter the gas market. Without the consent from the federal government, none of the gas companies would be allowed to operate. In return for the permission to sell gas, however, the gas companies must agree to provide gas to certain markets (such as small or isolated towns) within a certain range, even if those areas do not provide the firm with net economic benefits. In fact one executive stated that their company actually loses money by delivering gas to

[3] Most customers I spoke with purchase 20 kilo tanks. This would translate into an increase of about 4 pesos per month on the 20 Kg tanks

certain areas, but they are required to continue to do so by their contract with the federal government.

One further complaint given by one of the gas companies, not directly related to government policies, is that in the current system, the gas companies "pay" for the depreciation of the physical gas tanks over time and are responsible for decommissioning dysfunctional tanks. This is the case because once an individual purchases a single new metal gas tank, that specific tank is turned into the gas company and replaced with a full tank from the company's inventory. This saves the gas company the hassle of needing to fill up individual tanks on-site at homes or businesses, but also means that individuals only need to purchase a single tank of gas for their entire lifetime, and in the long run, the gas company is responsible for the depreciation of the individual tanks.

Figure 6: Delivering gas to a fixed tank on the roof of a tortilla shop.
The man below just handed off the hose to the man on the roof to do the fill-up.

In general, however, the gas companies appear quite confident that their business is sustainable and is not facing any serious threats from competing technologies. When asked specifically about solar water heaters, the president of Sonigas stated that he did not currently view the technology as a major threat to the current business model. He was not aware of the recent policy initiatives promoting solar water heating or their emerging use in new developments in the city, but did not feel that they would be a significant source of competition in the near term. He also immediately pointed out that the majority of the gas they sell is used for cooking, which generally requires boiling

water which cannot be provided by solar heaters alone and will continue to create demand for gas in homes.

Speaking with this man also helped to illustrate how individuals can even have several different perceptions of a single technology, depending on the specific context in which the technology is being framed. As a gas company executive, solar water heaters may be a potential competitor in some distant future, but as a citizen of Oaxaca, they may also be able to bring about positive changes. Although he was not aware of the Procalsol program or of the new developments using the solar heaters, he did appear to have a generally positive outlook for the long term potential of the technology. After reading through my hard copy of the Procalsol Policy documents, he sat back and briefly reflected and reaffirmed his belief that the technology did not presently pose a threat, but also expressed some belief that the technology may be a more significant presence sometime in the future. He stated that from his existing knowledge of the technology it may become a viable option someday, but that for now it was simply too expensive. Overall, however, he seemed to be optimistic about the technology, and in the long-term portrayed it as a generally positive step. He stated that "the key to allow for this technology is to get the initial price to a level where the people can afford it...and how nice that would be, because in the end it would really be for everyone's overall benefit."

In general, this gas company executive appeared genuinely interested in learning more about the technology. Yet, the fact that he was not at all aware of the significant activity surrounding solar water heaters in Oaxaca seems to reinforce notions related to the basic structure of a technological regime. The structure of a socio-technical regime is

understood as comprising of the rules and routines that guide the system in a relatively stable trajectory. These rules and routines begin with the designers and engineers, and become ingrained in the way that everyone involved tends to perceive the technology. In this case, it appears that the stable routines of the gas industry have created a situation where leaders of this industry are not aware of significant activity occurring to promote a new technology that may directly compete with gas based water heating systems. These rules and routines concerning what type of technology is needed to heat water may be very entrenched, and be leading to a relatively myopic view of how water can be heated.

DOMESTIC WATER HEATING IN OAXACA

While many highly centralized bureaucratic activities are taking place to encourage and manage the growth of domestic water heating industry in Mexico, there is little empirical work regarding how people actually value and use hot water. A series of brief interviews conducted throughout the city of Oaxaca illustrates the wide range of uses and ideas surrounding the use of hot water. When questioned as to what temperature of water is preferable to shower with, citizens replied with a range of answers from always cold to always hot, with several gradations in between. Many respondents indicated some type of variability with their hot water use depending on the season or the weather outside.

Specifically, all of the responses may be categorized as belonging to one of seven categories: always cold, seasonal but prefer cold, seasonal- no preference, seasonal but prefer warm/hot, mostly warm, mostly hot, and mixed household (Table 1). While it is true that the most common response given was a preference for hot water year round (15

people), almost the same amount of people (14) indicated that they prefer to bathe in cool water most of the year and only heat their water up for bathing during the winter.

Several respondents explained why they were averse to showering with hot water. One lady running a small corner store told me that she grew up with cold water and always felt that hot water gave her pains and made her whole body sore. Another man explained that he came from a warm coastal area and was so used to showering with cold water he never changed when he moved to the more temperate city. A third respondent explained that she generally liked using hot water, however did not trust solar heated water. *"They say that if you stay out in the sun you get too much radiation, so maybe some of that would get in the water too."* These diverse views on hot water challenge the implicit assumptions of policy makers that solar heated water is to be universally desired by everyone.

Table 1: Water temperatures for bathing in Oaxaca

Answer	**# of Responses**
Always Cold	9
Seasonal-prefer cold	14
Seasonal-no preference	4
Seasonal-Prefer Warm/Hot	4
Always Warm	10
Always Hot	15
Mixed Household	4
TOTAL	**60**

Respondents were also asked questions regarding the primary method that they used to heat their water for bathing (Table 2). While heating water with gas fired boilers was the most common method used, only about half of the respondents reported this as their primary water heating method. The other responses, in order of frequency, included the stove, firewood, and electricity. Several respondents also reported that they never heat water for bathing by any means.

Table 2: Methods for domestic water heating in Oaxaca

Answer	**# of Responses**
Boiler	33
Stove	16
Never	5
Firewood	4
Electricity	2
TOTAL	**60**

Additionally, all but one of the respondents who prefer hot water all year around also had boilers. This calls for investigation as to whether of whether these people chose to purchase a boiler because they know that they prefer hot water, or whether the presence of a boiler in the home and the relative ease of water heating have led to the preference for hot water. This survey indicates that there are many ways to value hot water as well as methods to heat water, but in the general public, solar water heating is not well represented.

In this survey, 29 of the 60 respondents indicated that they were unaware of solar water heating technologies. While just over half of the respondents were therefore aware of solar water heaters, this survey indicates that there is still a large portion of the population in Oaxaca who have not heard of these systems.

A closer examination the current systems of water heating has shown that there is a generally stable system of gas based water heating in operation throughout Oaxaca. This system is primarily based on gas boilers, but people use several other devices such as stovetops and electricity as well. While the majority of citizens in Oaxaca do value hot water for at least part of the year, it appears that there actual views on hot water are quite nuanced.

PRICE OF GAS BOILERS AND GAS LP

As gas boilers currently comprise the most significant method for water heating in Oaxaca, these systems will make up the main competition for solar water heaters. Additionally, there has been a significant increase recently in the availability and use of on-demand gas heaters, which may represent another significant source of competition for solar water heaters. On the other hand, these systems may be viewed as more complimentary than competitive. In fact, several SWHs throughout the city already come equipped with an on-demand heater as a backup system. With these systems, if the water leaves the solar heater below a certain temperature, the passive heater automatically turns on and the water is fully hot by the time it reaches the outlet. Whatever the relationship is between all of these systems, people will undoubtedly be comparing prices between them when deciding what type of water heater to purchase.

Economically, the initial cost of both the traditional boilers and the on-demand units are significantly less than current prices for solar water heaters. As a rough average, the gas based systems can be purchased for between around $1,500 and $2,500 MXP (Fig. 7). By comparison, SWHs typically cost around $10,000. This is clearly a very significant difference. For many Oaxacan families, it is nearly impossible to defer such significant financial advantages in the initial costs for potential savings several years in the future.

A large part of this difference can be explained by the materials being used; SWHs require expensive copper or evacuated glass tubes. SWHs are also often shipped in from other countries such as China and Germany. In fact, I was told (by the owner of a store that sells SWHs) that there are no companies currently manufacturing glass tube SWHs anywhere in Mexico. Another reason for this huge difference in price may be that production of SWHs in Mexico has yet to achieve economies of scale necessary to bring the prices down significantly. In fact, current policies aimed at increasing the use of SWHs in Mexico are explicitly designed to lower the price through economies of scale.

Figure 7: A gas boiler, toilet, sink, and accessories for under 2,400 MXP.
A typical solar water costs around 10,000 MXP

Nonetheless, the fact remains that SWHs are significantly more expensive up-front than gas-based systems. The only reason that SWHs can even begin to compete from an economic perspective, is because they require far less fuel over the lifetime of the system (Although the SWH itself consumes no fuel other than sunlight, they are typically installed with a backup gas system). When conditions are right, SWHs will provide ample hot water using only the sun. Although some fuel for water heating may be used if it is cloudy for extended periods, most proponents of SWHs claim that they can provide 60-80% of the water heating demands of an average household throughout the course of a year. In my research I found many people who had not turned on the boiler a single time after having a SWH installed on their home. The question then becomes, "can the savings in fuel over the course of several years make up for the additional up-front cost? And if so, how long will that take?"

In order to begin to examine this question, it will be helpful to look at the price of natural gas, and how it has changed over the course of the last decade (Table 3). The price of natural gas in Oaxaca, as in the rest of Mexico, is directly tied to the prices in the US, and specifically tied to the markets in South Texas (García and Curiel 2005). The price of gas in Oaxaca, while remaining relatively steady over the last several years, has nonetheless more than doubled over the course of the last decade. In fact, from Aug of 2001 to July 2011, the price of Gas LP in Oaxaca increased about 131%. However, most of this increase The following chart gives the prices, in MXP per kilogram, of natural gas prices in Oaxaca.

DATE (JULY OF YEAR)	(AUG) 2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Gas price (MXP/Kilo)	4.51	5.27	6.46	7.18	8.88	9.07	9.49	9.82	9.34	9.79	10.44

Table 3: price of Gas LP in Oaxaca since 2001

While this chart is useful to get a general idea of how the price of Gas LP has changed in Oaxaca over the course of the last 10 years, it is still impossible to tell how the price of gas will change in the future. Additionally, there are other important variables (such as the amount of hot water required and the actual efficiency of the specific system) which make it impossible to give an accurate forecast for the payback period of SWHs in generally. Instead, all of these specific factors, as well as the actual rate of change for gas prices, would need to be taken into consideration to determine the payback period possible for individual owners.

While the large majority of homes and businesses today do use Gas LP to heat their water for domestic purposes, there has been significant effort to encourage the use of a device that does not rely on gas LP. The following chapter will examine the formation of a nation-wide policy to encourage solar water heaters and the various sources--organizations, interests, and influences--that led to the creation of this policy.

Chapter 4: Solar Water Heating

Although water heating in Oaxaca is not a universally demanded service, we have seen that a large majority of the city does use liquid petroleum gas to heat water for domestic purposes, for at least part of the year. This relatively inefficient system of gas water heating requires gas to be delivered to individual buildings by gas trucks that form a constant, if mobile, part of the urban landscape of the city. However, many policymakers have noted that Mexico has many attractive conditions for the use of solar water heating technology. With ample solar radiation, a mature technology, and evidence of successful programs in other regions of the world, there have been continuous efforts at creating a domestic solar water heating industry in Mexico for several decades (Procalsol). These efforts have been hampered by a range of factors, however, and this industry has never truly been able to achieve significant market penetration in Mexico. In 2007, the Mexican Secretary of Energy released a major policy initiative designed to encourage a large scale shift towards the use of solar water heaters. This chapter will introduce solar thermal technology, discuss awareness and education regarding solar water heaters in Oaxaca, give a brief overview of the formation of the Procalsol policy and analyze how powerful institutions are influencing the physical form solar water heaters are taking in Oaxaca.

SOLAR WATER HEATING- STATE OF THE TECHNOLOGY

Generally speaking, solar water heating utilizes technology that is well understood and developed (Chang et al 2007, Langness and Ince 2004, Mishra 1991).

The basic idea of a solar water heater is simple: when water is placed out in the sun, the water will heat up and provide hot water for bathing and other domestic purposes. Because solar water heaters work by harnessing the sun's energy for heat, they are best classified as a solar thermal technology. In this sense, the simplest solar water heaters are simply buckets of water purposefully left out in the sun to heat up (In fact one lady selling peaches spread out on a blanket on the sidewalk, outside of a local market, told me that she already uses solar water heating because she leaves a bucket of water outside every morning to heat up by the evening). Specially designed and engineered solar water heaters utilize conductive materials and simple designs to accelerate this process so that as much water can be heated in as little time, and with as little sun and heat, as possible. Throughout the world, there are various types of solar water heaters that may be categorized based on specifications such as whether the water is heated directly or heated through an intermediary liquid (such as antifreeze), whether or not the system requires any external power (usually for a pump), whether the system is closed or open loop, and what types of materials are used for the component parts (US Dept. of Energy).

While there are many types of solar water heaters on the market, the most suitable type of solar water heater in Mexico is a direct-passive thermosiphon version (Fig 8). This type of system is "direct" because it directly heats the water for end-use (as opposed to heating an intermediary liquid first), "passive" because it requires no additional energy inputs (such as pumps), and "thermosiphon" because of the way that water flows through the system based on the thermosiphon principle of natural circulation. This principle describes how as water is heated it becomes less dense and will rise to the top of cooler

surrounding water (this is analogous to the more widely known phenomena of hot air rising above cooler air). Because the hot water naturally rises to the top, the water can flow through the entire system without the need for a pump.

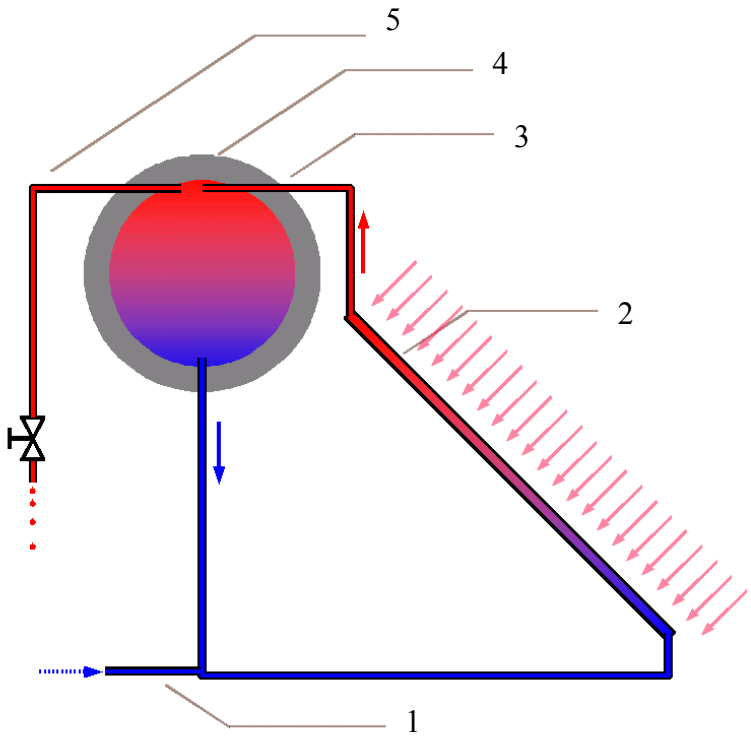

Figure 8: Diagram of a thermosiphon solar water heater.
(adopted from Bielefeld 2006).

1) Cool water enters the panel from the water tank (*tinaco)* on the roof and the bottom of the insulated tank.
2) As water heats up in the panel, the warm water rises to the top
3) The hottest water reaches the insulated tank, where it stays at the top
4) The insulated tank stores hot water for use, as it is needed
5) The hottest water, at the top of the tank, leaves the tank to be used in the home

In a thermosiphon water heater, all of the water enters the system through the bottom, and as some of the water begins to heat up, that water rises through the heating tubes until the hottest water is at the very top. Once it reaches the top of the heating tubes, it drains out into an insulated tank, where this newly heated water will again rise to the top of this tank. These insulated tanks function like giant thermoses, and are generally designed to store about two days' worth of hot water. This type of thermosiphon solar hot water heater has been described as one of the simplest and most widely used solar energy devices in the world (Kalogirou 2009). As I will discuss later however, while this general system describes those being installed in Oaxaca, the main material of the conductive pipes for these particular systems is still being negotiated between various stakeholders.

Thermosiphon systems work better than other technologies for a number of reasons, including the climate and the water delivery and plumbing system in the city. The climate of Oaxaca City is classified as dry-temperate and does not freeze during the winter. This means that the heaters can run water through their pipes without ever freezing, and can therefore directly heat the water without an intermediary heating liquid. If Oaxaca were prone to freezing, it would have to use more expensive indirect methods of solar water heating. Additionally, the way homes and buildings store water on the roof in Oaxaca means that these solar water heaters do not have to rely on any additional energy inputs. The water supply for a home or a building is generally stored in large

plastic containers known as *tinacos* that are placed on a slightly elevated surface on a flat roof. As the solar water heaters are placed slightly below these tanks, the water simply follows gravity and flows down into the bottom of the heating unit where it upward circulates through thermosiphon. In this way these heaters do not require any additional energy inputs.

Studies in different geographical contexts throughout the world have been conducted to assess the environmental and economic performance of solar water heaters Han et al. 2010, Kalogirou 2009, Purohit and Michaelowa 2008, Srinivisan 2006Tsilingiridis et al 2004). In terms of both environmental and economic benefits, solar water heaters, when installed and used properly, have been shown to be "efficient, cost effective, and friendlier to the environment" compared to traditional fossil-fuel based systems. (Kalogirou 2009). One study found that similar systems being used in Greece could account for about 80% of the hot water needs of a family of four and could pay for itself in 2-5 years. Overall, empirical research conducted throughout the world has shown that solar water heaters have the potential to generate net environmental and economic benefits.

INTERNATIONAL POLICY EXPERIENCE WITH SOLAR WATER HEATERS

The technology for solar water heaters is well developed and, encouraged by a variety of policy initiatives has actually become fully integrated into the economies and energy mixes of several countries; Israel, Barbados, Greece and Turkey represent a few countries where this technology is used by a significant portion of the population (Langness and Ince 2004, Srinivasan 2008). In Israel, for example, it has been noted that

"by 2006 almost every household in Israel owned a solar water heater" (Roulleau and Lloyd 2008).

Solar water heaters have also been examined specifically in the context of other developing countries. It was estimated that as of 2002, there are at least 15 million units installed in the developing world (Martinot et al. 2002). China represents about 2/3 of this number, with about 10 million households using SWHs (Martinot et al 2002). Emerging markets have been identified throughout the world, where developing countries, often with warm climates, are turning to solar heating technology. In Thailand, for example, solar water heaters represent about 15% of the water heater market (Timilsina 2000). The climate throughout much of Mexico, and the state of Oaxaca, is especially amenable to this type of technology. The state of Oaxaca averages over 5 KHz/m^2/day in many parts of the state, similar to much of the Southwestern United States (NREL).

In nearly every case of a substantial solar water heating market, there has been significant government assistance to help establish a base market. Roulleau and Lloyd have identified five categories of policies which have been used throughout the world to promote the use of solar water heaters: collector-area based subsidies, performance based subsidies, tax credits, tax deduction, and mandatory policies (Roulleau and Lloyd 2008). As we will see, Mexico is currently pursuing a unique policy mix to encourage the use of solar water heaters that is primarily being implemented through their national mortgage agency.

LANDSCAPE-LEVEL CHANGES

Efforts in the private and public sector to generate a solar water heating industry in Mexico have existed for several decades, but it is only within the last few years that significant progress has been made. At least two developments in recent years may have helped to create the context which allowed for the creation of the current policies. Generally, these contextual changes are related to a growing economy with an expanding middle class of homeowners, and the recognition of the existence of global climate change. Specifically, Mexico has seen a dramatic increase in the number of new homes being built as well as overseen the creation of the Special Program on Climate Change. As is true with any phenomenon, there were clearly many other factors (political, economic, etc…) that led to these specific changes (the increase in the number of houses and the creation of a climate change program), however both of these appear to directly affect the context for the emerging use of solar water heaters.

The Mexican Housing Market

In an analysis carried out prior to the actual publishing of Procalsol, data was gathered regarding the residential construction industry in Mexico. It was determined that in 2005, between 700,000 and 800,000 new homes were built (Hoyt et al 2006, p. 14). Of these homes, slightly less than half were constructed on an individual basis and financed by the home owners themselves (these homes were usually funded with remissions brought in from abroad) (Ibid). The other half of the new homes were constructed by large developers in what has been labeled the "formal" market. Many of these homes are in *fraccionamientos* (similar to American subdivisions) which are built

as speculative homes by the developers This formal housing market is estimated to have grown by up to 45% between 2001 and 2004, an increase that is substantiated by a similar increase of 50% in the number of mortgages taken out in 2005 compared to 2001(Ibid p. 14).

This dramatic shift in the entire housing landscape in Mexico may be a crucial component for understanding the emergence of solar water heating systems at the residential level. As the number of mortgages and new homes being built in Mexico has steeply increased over the last decade, opportunities for economies of scale, and soaring demand for new appliances, may have provided a major impetus for promoting this new type of water heating technology.

In addition to these dramatic shifts in the domestic changing housing market, growing awareness of the environmental problems associated with the use of fossil fuels created an additional incentive to develop a policy to encourage solar water heating.

Special Climate Change Program

The Special Program on Climate Change or PECC (*El Programa Especial de Cambio Climático),* is an initiative of the Mexican Federal Government based on 105 objectives and 294 goals designed to "show that it is possible to mitigate and adapt oneself to climate change without compromising processes of development and or economic benefits (Semarnat). One of these objectives (2.1.2) is to "reduce emissions associated with the production, transport, and distribution of natural gas". As we have seen, the system for natural gas delivery is highly inefficient, requiring fleets of trucks to deliver tanks of gas to every individual home and business. The PECC states that "there

are several sources of renewable energies that have a great potential to replace or substitute for the consumption of gas in diverse sectors…in particular, the profitability of solar water heaters has been established throughout the world, including in Mexico. It will be fundamental for the PECC to promote these alternatives" (Semarnat).

With the massive development in the national housing market and the creation of a program to reduce greenhouse gas emissions, Mexico prepared to launch an initiative to jumpstart the use of solar water heaters. Before I describe these policies and mechanisms, it may be useful to get a better understanding of overall levels of awareness and education regarding solar water heaters in Mexico and Oaxaca.

SOLAR WATER HEATING IN MEXICO AND OAXACA DE JUÁREZ

Awareness

Although the technology for SWHs is well developed and becoming increasingly utilized around the world, a recent study (Mallet 2007), as well as my own research, indicate that they remain relatively unknown in many parts of Mexico, including Oaxaca. A study on SWHs in Mexico City in 2006 found that *"Regarding knowledge, in Mexico, there is generally a lack of awareness among potential users about this technology…"* (Mallet 2007). In my experiences, I found that about 2/3 (33/48) of respondents were unaware of SWHs. During an interview with a shop-owner who specializes in installing SWHs, he explained the difficult time they faced in informing people about the technology:

> …We had to make an effort to go out and convince people. What we were looking for was that the public in general, that society in general, found out that this technology existed…That was the first stage that we considered difficult to

> start to try to do- going to conferences and institutions, somehow making presentations in public spaces, so that the people would find out about this new technology…(XAM from Solar MAX).

SWH in the Media

Although there is a relative lack of awareness about SWHs in Oaxaca, there has been some coverage of the emergence of the technology in the local media. Several people that I spoke with throughout the city mentioned that they had heard about solar water heaters either through the TV or one of the local newspapers. The managers of the new solar water heating shop also described the role of the media and the internet in spreading awareness of solar water heating technology in Oaxaca:

> "Yea actually there are journalists and other types of writers who are also interested in this, in the technology. We have gotten to the point that they write about us, like in this case (he points up to the wall of a blown up article from a local newspaper about the business). So they give this information out, they try to spread it out to the general public. So through the newspaper, and also through the internet they are giving out our address and telling people that we are working with solar energy."

I found that each of the three leading periodicals in Oaxaca, *El Imparcial*, *Noticias Voz Y Imagen Oaxaca,* and *Diario Despertar,* have run stories relating to solar water heaters in the city (Flores 2011, Juárez 2010, Palencia 2010, Torres 2010, Consejos 2009) [45678]. A November 4, 2010 article from *El Imparcial*, for example, explains the

4 http://www.imparcialenlinea.com/index.php?mod=leer&id=117704&sec=primera&titulo=Infonavit_apuesta_a_%93hipotecas_verdes%94

5 http://www.imparcialenlinea.com/index.php?mod=leer&id=109357&sec=primera&titulo=Impulsa_viviendas_sustentables_Inmobiliaria_Aguilar_del_Sureste

Infonavit "Green Mortgage" program, highlighting solar water heaters as part of the package of "eco-technologies" that are designed to improve quality of life while saving both money and natural resources (Juárez 2010). Another article in *Diario Despertar*, "Green Advice for Everyday Living", advises readers that by installing a solar water heater they can substantially reduce their gas consumption, and recoup the initial investment in a time frame of 3-6 years (Consejos 2009).

While the media and advertising have certainly played a role in informing citizens about solar water heaters, formal research and educational programs such as trade schools and universities have also been established to raise levels of awareness and knowledge about the technology

Research, Education, and Technical Training

Peer-to peer learning is widely regarded as a key component of the process of the diffusion of innovations (Rogers 2005). However, formal education and training is also an important part of ensuring a new technology is fully understood and able to be properly installed and utilized. In order to investigate what type of formal education systems related to solar water heaters had arisen in Oaxaca, I spoke with a number of professors, engineers, and SWH installers. While speaking with the owner of a solar hot water heating store, I was informed about a new university just outside of the city that is

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6 http://www.imparcialenlinea.com/index.php?mod=leer&id=121831&sec=opinion&titulo=POR_LA_ESPIRAL

7 http://www.noticiasnet.mx/portal/principal/inaugura-aleida-serrano-feria-energias-renovables

8 http://www.diariodespertar.com.mx/suplemento/6564-CONSEJOS-VERDES-PARA-TODOS-LOS-DIAS.html

now offering degrees and technical training programs in Alternative Energy Engineering- the Technical University of the Central Valleys.

The Technical University of the Central Valley (*Universidad Tecnico de las Valles Centrales)* is a school many years in development, which just began formal classes in August 2009, about one year prior to my research. The school is located in the Southern part of the Central Valley, about 30 minutes by bus towards the Sierra Sur Mountains from Oaxaca City, in the town of San Pablo Huixtepec. The small town was very calm and quiet on the day I came to the University, and the buzz of young students around the school was by far the most activity around the center of the town. The school itself was actually still in the process of being built, so for this year the students' classes were being taught in the two-story municipal buildings adjacent to the *zocalo*. The official campus will be located slightly outside of San Pablo Huixtepec when construction is completed.

TUCV is one of only eight schools nationwide to offer a 4 year degree program in Renewable Energy Engineering. They also offer a Master's degree in the same program (a program which is now being offered online as well). I spoke at length with Juan, the dean of the department of Renewable Energy, about how the school functions and has performed after the first year in operation. In general, he seemed very positive about the present state of the school and the prospects for the future. He feels as if they are training a new generation of skilled workers in an emerging industry that will continue to grow in Oaxaca.

The students in this department have the option of earning either a technician certificate or a full engineering degree. He described these two options,

> We are an engineering department, and we have two different degrees: The technical and the engineering. If the student doesn't want to keep studying, after two years they can receive a (Tecnico Superior) certificate, registro, and they can go out and work. If they want to keep studying they can get to the level of engineer. When you go for the engineering program, you get two titles; that of technician and also of engineer.

Another school that at first appeared to be actively involved in research in SWH was the Technological Institute of Oaxaca, an established and demanding private university in Oaxaca City. After speaking with professors in various departments, from Community Development to Engineering, I found the department of Materials Science to be the field most closely working with solar energy; however there did not appear to be any active research into solar water heating. I spoke with Dr. Nira, a materials scientist in the bio-chemistry department, about any research being done on SWH in Oaxaca, and while they had done some research on photovoltaic cells, they had not conducted any research on solar thermal. She referred me to the University Anahuac, located about 20 minutes from downtown Oaxaca in Xoxocatlan, where I spoke with a mechanical engineer and another materials scientist. While they both had some knowledge of SWHs, neither could speak of active research taking place in Oaxaca. This lack of research activity appears to support the general consensus that solar water heaters are a relatively mature technology, with significant empirical data indicating how they have functioned in various regions.

Parties interested in the successful diffusion of solar water heaters in Mexico have also explicitly indicated the need for increased levels of formal education regarding solar water heaters in Mexico. GTZ[9], for example, is a German aid institution helping to formulate the policies designed to encourage the use of SWHs. They explain that

> "…GTZ Mexico is also committed to improving and expanding training courses, for instance, by identifying training institutions and certification mechanisms for plumbers, by developing training courses and materials, and by producing a general installation handbook" (GTZ)

During my research in Oaxaca, I was able to spend several days working with an installation crew installing solar water heaters on the rooftops of hotels in downtown Oaxaca. The group I was working with consisted of six men; four electrical engineers, and two men experienced in construction and air conditioning installations. Their experience with solar water heaters mirrored the recent emergence of the systems throughout the city; the most experienced had been installing the systems for about 15 months, while the most recent had barely two weeks of experience. They explained how, while they were all relatively new at installing solar water heaters, their past experiences were very transferable to this work and that the technical aspects of installing these systems seemed to be relatively simple.

One electrical engineer explained how, "For me it hasn't been very difficult to switch from working with electrical to hydraulic systems; it has mainly been a change in materials. I used to work with cables, and now I work with pipes and tubes." While they are often learning through doing, they told me that they also are taking more formal

[9] As of January 2011 GTZ changed their name to GIZ

courses every weekend with the owner of their company, who has several certifications and many years of experience with solar water heaters. "While you are out in the field, you can have specific instructions and know exactly what to do, but you may not know why. During these courses we learn all of the theory behind the technology so we know why everything functions like it does."

They felt that learning specifically about solar water heaters was very important and that plumbers who attempt to install them without this proper training often make mistakes. It was also apparent how recently the pace of installations had picked up:

> I have been with the company for about a year, but it just started in January when we really started to pick up and have steady work…one after the other after the other. We're working now without any set salary. We're trying to get started along with the product. We know that with time all of this is going to grow. So we want to get in on that inertia. Then when the real 'boom' happens, we'll be trained and ready take advantage of it. That's where we see the benefit for us

As a long term process, formal education systems will need to play an important role in raising awareness and spreading knowledge of the new technology. While a technology may be fully mature, it will also require knowledgeable people to explain, install and maintain it. If some change happens that provides an opportunity for a niche technology like SWH to challenge the incumbent system, having a sufficient amount of educated and trained supporters will play an important role in determining whether the niche technology can take advantage of this opportunity or not. A key aspect of the multi-level perspective on technological transitions relates to the timing of the interactions between the landscape, regime and niche levels. Geels and Schot (2007)

explain that "if landscape pressure occurs at a time when niche-innovations are *not* yet fully developed, the transition path will be different than when they *are* fully developed."

While the technology for solar water heating does appear to be quite developed and ready for the market, the availability of knowledgeable installation, support, and maintenance personnel is only beginning to emerge. It does appear that there is significant educational activity relating to solar water heaters around Oaxaca, with a new university offering engineering and vocational training, courses offered by local shop-owners and engineers, and on-the-job learning by installation crews with transferable skill sets. Even if the technology is ready for market, if systems are installed incorrectly, due to lack of knowledge or education available, that can lead to a ripple effect of negative perceptions, greatly hindering efforts at widespread diffusion. As it currently stands, many people are working hard to prevent this from happening in Oaxaca.

Chapter 5: Procalsol- The Program to Promote the Use of Solar Water Heaters in Mexico

Efforts aimed at fostering a domestic solar water heating industry, involving academic institutions, researchers, and businesses have existed in Mexico for over thirty years, but persistent problems with funding and quality standards as well as poor coordination among stakeholders perpetually plagued these efforts (GTZ). Over the last few years however, tens of thousands of solar water heaters have been installed and the overall awareness of the technology has undoubtedly been rising. This dramatic surge in the use of SWHs is directly tied to a policy report entitled Procalsol or The Program for the Promotion of Solar Water Heaters in Oaxaca (for the Spanish acronym, *Programa para la Promoción de Calentadores Solares*). This report was published by the Mexican Secretary of Energy in 2007 and stems from recent efforts by a large contingent of institutions and organizations from the policy, academic, and technical areas, aimed at assessing the potential and encouraging the growth of a solar water heating industry.

While this specific policy is relatively new, Mexico has indicated support for environmental agreements and policies regarding energy policy for a number of years. Mexico ratified the UNFCCC in 1993, developed a National Action Plan for Climate Change in 1997, ratified the Kyoto Protocol in 2000, and explicitly called for environmental care in the energy sector (through increasing the use of renewable energy) in the National Development Plan 2001-2006 (Huacuz 2005). In 2005 Mexico was described as being "dormant" in the field of developing local renewable energy industries; lagging behind other OECD countries in terms of the practical applications of

renewable and also structuring the necessary policies, programs and infrastructure to foster their growth (Huacuz 2005). *The government of Mexico is actively seeking to encourage increased utilization of renewable sources of energy; however, Mexico has not been able to keep up with the rapid growth in other similarly developed countries such as China and India (Huacuz 2005, 2).*

As Mexico has sought ways to increase the use of renewable energy technologies, research from a number of sources began to highlight solar water heating as a viable area to concentrate policy efforts at the residential level. In the years leading up to the 2007 Procalsol report, a number of broad contextual shifts were occurring in Mexico that would create the context under which the Procalsol policy would operate. One important such shift is related to the broad changes that have been occurring in the Mexican housing market.

The Procalsol policy, formally introduced in 2007, indicated that solar water heaters represent an economically viable and environmentally responsible option for water heating in Mexico. Depending on various factors such as available interest rates, exact price of equipment, amount of water heating required, and price of gas, the report estimated a payback period, at the household level, of between 4-8 years.

At the same time, Procalsol recognized that there were still significant barriers that were preventing solar water heaters from becoming more widely adopted. The report describes the four most important limitations to wide-spread adoption as being 1) high initial costs for equipment; 2) limited access to financial lending mechanisms; 3) lack of awareness or mistrust of the technology, and 4) lack of technical expertise for

manufacturing, installation, and maintenance. Each of these issues has specific guidelines set up to address them, which are supposed to be overseen by the National Commission for Energy Savings.

This report describes solar water heaters in Mexico in a largely positive light by forecasting a large potential market for the use of SWHs in Mexico, the growth of which would result in both economic and environmental benefits. According to Procalsol, *"Solar water heating is a process that can be more economical than using fossil fuels, and has practically no negative environmental impacts"* (Procalsol 2007). After an analysis of fossil fuel costs and various financing mechanisms, the report concludes that currently *"for many applications, it is more economical to use the solar alternative than fossil fuels."* (Procalsol 2007). Additionally, the report estimates that if all current water heating applications were replaced with solar technologies, consumers would save around 49 Billion Pesos (about 4 Billion USD) annually in the consumption of fossil fuel resources. On the environmental side, such a transition would result in a reduction of around 4 million tons of CO2 equivalents a year (Procalsol). These figures, however only give the maximum potential values if all the energy presently used for water heating was to be immediately replaced with solar heaters.

In order to better understand the formation of Procalsol, and what affect it may ultimately have on introducing this new technology to Mexican society, it will be informative to examine some of the main interests and organizations that helped to conceive it. Viewed through the multi-level perspective, these policies help to create a niche level for this nascent innovation to grow. Over a dozen organizations have been

actively engaged in producing a policy to foster the growth of a new technology and industry. The recent efforts of these groups, and their request for a more comprehensive multi-sectoral program, are explicitly stated as a prime reason for the creation of Procalsol (Procalsol). Amongst this alphabet soup of involved organizations, a few of these groups played a significant role in the formation of the actual Procalsol document and thus deserve special attention.

GTZ/GIZ

The Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) is a corporation owned by the German federal government dedicated to implementing sustainable development projects in foreign countries. Founded in 1975 and with ongoing operations in 128 countries around the world, their stated corporate objective is "to improve people's lives on a sustainable basis." GTZ describes their core competency as "capacity development", which involves supporting “people, organizations and societies in developing and emerging countries as they undergo the learning and change processes needed to achieve lasting results”. (In January of 2011, GTZ formally changed its name to the GIZ [Deutsche Gesellschaft für Internationale Zusammenarbeit or German Society for International Cooperation], reflecting a merger with several other German aid organizations.)

Figure 9: A diagram explaining the new subsidy program.
It shows that the "Green Mortgage Program" (Hipoteca Verde) and the German aid organization GTZ are working to bring "Subsidies for Solar Water Heaters" (Infonavit).

GIZ is actively involved in several large environmental projects in Mexico such as an integrated waste management program in Tamaulipas and an environmental management training program in Queretaro. Two of these projects directly address the issue of increasing the use of solar water heaters in Mexico: Support for the Program to Promote Solar Water Heating in Mexico (Procalsol) and 25,000 Solar Roofs for Mexico. In fact, GTZ helped to conduct significant research projects relating to solar water heating potential in Mexico in the years prior to the development of the Procalsol Policy (*Financial Alternatives for the Promotion of Solar Water Heaters in the Domestic Sector in Mexico* and *International Experiences with Solar Water Heaters*). The involvement of the GIZ provided a large impetus for the creation of the Procalsol, with high levels of interaction occurring between the office of the Mexican Secretary of Energy and the GTZ (at least one former Mexican government employee during the formation of Procalsol is now managing a related development program in Mexico for the GTZ).

During my research, I was able to speak with one employee of the GTZ, who further explained the prominent role the GTZ has played in encouraging the use of solar water heaters in Oaxaca and throughout Mexico. He told me that GTZ has been active in the creation of the Procalsol policy from the very inception in around 2005. He explained

that they have assisted from the early stages of carrying out preliminary research, to helping to manage two separate programs which are seeking to install a combined 50,000 water heaters in 2011. The role of GTZ will be further explored as it relates to these two specific programs.

PROCOBRE

Another important group involved in the formation of Procalsol was the Latin American branch of the International Copper Association, ProCobre. According to their website, ProCobre is *"a network of Latin-American institutions whose mission is the promotion of the use of copper, stimulating research and the development of new applications and promoting copper's contribution to the improvement of the quality of life and the progress of society."* PROCOBRE is part of the International Copper Association (ICA), based in New York, and in charge of leading copper promotion on the global level. According to the GTZ website,

> PROCOBRE itself is responsible for conducting training seminars for plumbers and technicians as well as courses intended to enhance the supply side. Moreover, the copper association is developing voluntary standards for solar thermal energy systems and their installation as well as designing a website on solar thermal energy in the residential sector.

Clearly then, the International Copper Association has been highly involved in the formation of the Procalsol policy.

What makes the copper industry's involvement in this project interesting is the fact that there are currently two competing categories of thermosiphon solar water heaters; one of which uses copper pipes and another which uses evacuated glass tubes. Each version of the technology can claim certain advantages and disadvantages compared

to the other and neither material appears to be clearly superior. Different markets throughout the world differ greatly in the type of material used for thermosiphon solar water heaters used. In China, for example 95.35% of SWHs were evacuated tube systems as of 2007, while in the EU 85.94% of systems used the flat plate copper systems (Han et al 2010).

Table 3: Pros and Cons of Copper vs. Glass Solar Water Heater

	AVG. PRICE, MXP (150 LITERS)	**DURABILITY**	**EFFECTIVENESS**	**INSTALLATION AND MAINTENANCE**
Evacuated Glass Tube	7,829	More fragile	Generally considered more effective and efficient at heating water- both in the sun and in cloudy conditions. Water can be heated to 80 C.	More difficult to install
Copper Tubes	10,523.67	More durable	Still very effective at heating water in sunny conditions, but less so when cloudy. Water can be heated to 60 C.	Easier to install

In the case of solar water heaters in Oaxaca, the final form of the technology is still being negotiated and both the copper and glass versions are being sold and used throughout the city. Hardware stores and alternative energy shops in the city usually sell one version or the other and defend that version as generally superior.

For example, the owner of alternative energy store in Oaxaca who sells the copper version explained that he felt the glass versions are too fragile and will ultimately require more repair and maintenance.

> Principally the Chinese models of the glass tubes…I trust more in the copper type than the tube models. Some people tell me that there are really good glass tube models available, but not the Chinese ones eh? The Chinese ones are very fragile….very fragile. Even though they tell me that they can reach a higher temperature than the thermal copper models I still prefer the copper".

What type of influence then, has the International Copper Association had on shaping the final form that this technology takes in Mexico and in Oaxaca? As scholars of technology and society tell us, the final form and uses of any technology do not follow a straight historical trajectory or evolve based on any inherent logic embedded in the technology. They always "might have been otherwise" under different sets of historical circumstances (Bijker and Law 1992). In the book, *Inventing American Broadcasting*, Susan Douglas examines how "major institutions, such as General Electric, American Telephone and Telegraphe and the U.S. Navy, influenced the invention's (radio's) evolution...Like virtually all emerging technologies, radio did not simply appear one day in its fully realized form..." (Douglas 1987). The case of solar water heaters in Oaxaca

also highlights the idea that technologies evolve based on complex interactions and the demands of powerful stakeholders which may not be obvious to end users.

One familiar analogy may be to compare this situation to the videotape "format war" in the late 1970's and early 1980s when Sony's Betamax was battling for market share with JVC's VHS model. Although Sony's Betamax had a seemingly insurmountable lead in market share in 1975, by 1977 JVC had "set in motion the fundamental forces that would continually erode, and then extinguish, Beta's share of a massive global market" (Cusumano et al 1992). Although there may be a tendency to think that VHS won because it was simply a "better" product, this case illustrates how the actual evolution of the technology was much more complicated. Were it not for a series of strategic decisions and alliances with producers and distributors VHS may not have beaten out the Beta system. Cusumano et al (1992) explain that

> In retrospect, it is possible to identify the key events and to "explain" the outcome in terms of a few factors. But as events were unfolding, the implications of each strategic move must have been more difficult to discern. Each of the key protagonists acted in a way that made sense in context.

As copper and glass heaters compete for dominance, it is similarly impossible to say which of these versions of the technology (if either) will ultimately become the accepted form in Oaxaca. The fact that these two versions are still competing with each other shows that significant questions about the final form of the technology itself still remain and the technology is still in the process of being "constructed". As has happened with other competing versions of technologies, it is not necessarily the "best" version that succeeds. In the large developments where the emergence of solar water heaters is most

directly influenced by the Procalsol policy, all of the homes I observed during my research were using the copper-based heaters. However, it appears that since then there have been changes in the official policy that may counter claims about the influence of PROCOBRE in determining the final form of the heaters in Oaxaca. As of April 2011, about 54% of all heaters installed through the HV program have been evacuated glass models, while the remaining 46% have been copper tube models.

During the Spring of 2011, I noticed a new section on the Infonavit website detailing the eco-technologies that should be included on "Green Mortgage" homes. In this online document, every reference to solar water heaters described them specifically as "evacuated tube solar water heaters". Throughout the Infonavit site, both copper and evacuated tube versions of SWHs are discussed as viable options. It appears, then, that although the International Copper Association played a prominent role in designing the program to promote solar water heaters in Mexico, market demand, or some other factors, are pushing this technology towards the evacuated tube version.

INFONAVIT- INSTITUTE OF THE NATIONAL FUND FOR WORKER'S HOUSING

Infonavit is the national mortgage lending agency of Mexico whose goal is to provide financial support for the housing needs of employees of private companies. Currently, Infonavit is engaged in two large programs designed to put the policies of Procalsol in to action: the "*Green Mortgage*" (*Hipoteca Verde)* program and "*25,000 Solar Rooftops*" (*25,000 Techos Solares).*

Since the findings of the 2007 Procalsol report, the federal government has implemented a number of measures to encourage the use of SWHs by consumers. One of

the most direct links that the government has with residential units is through this federal mortgage agency "The Institute for the National Workers Housing Fund", known throughout the country as Infonavit. In fact, Infonavit is the main institution through which the policies designed to foster the growth of solar water heater use in Mexico are being implemented.

Hipoteca Verde (the Green Mortgage Program)

According to the Infonavit website, the Green Mortgage program is designed to allow for additional loans (of around $20,000MXP) to homeowners in order to purchase a package of "eco-technologies" for their homes. While many components of this package are similar throughout the country, the specific technologies that are included in the package depend on the geographic location of the home to account for climatic differences. In Oaxaca, the package of eco-technologies consists of items such as energy efficient light bulbs, low pressure shower heads, and solar water heaters. Developers, then, generally build homes already equipped with these devices in order to qualify for this program. Infonavit will then provide the additional loan so that buyers can cover the buy the package of eco-technologies that has been added on to the price of the home. The cost of the entire eco-technology package, mainly comprised of the cost of the SWH, is listed online as $18,185.28 MXP, and is factored in to the mortgage. Of this price, the bulk goes to the SWHs, but some goes to other pieces of "eco-technologies". I was never able to obtain an itemized breakdown, but I was told that the SWH makes up by far the largest part of the loan. For the sake of gaining some understanding, I will say that the SWH portion of the loan is 14,000 MXP.

Economically, the program is justified to the homeowners by claiming that the monthly energy savings in gas and electricity from the use of these eco-technologies will be sufficient to cover the additional costs of the mortgage (Infonavit). In other words, residents in these houses should expect to realize more savings per month from reduced energy use than the additional payments per month for the eco-technologies. This is an excellent idea in theory, and when the technologies are installed and being used correctly it does appear to function in this way. For example, I spoke with several homeowners in the San Jeronimo subdivision who told me that they had not used the gas boiler to heat water for showers at all since they had arrived. On average, these homes used to use about one 200 Kg tank of gas per month for water heating, at a cost of about 200 MXP. Infonavit estimates that households will realize savings of 215 MXP per month, which in the ideal scenario, seems to be in line with reported savings of about 200 MXP/Month in reduced gas usage[10].

If the $14,000 loan is paid for with a 5% interest[11], the homeowner would pay for the system with 360 monthly payments of $75.16 and the total cost paid throughout the 30 years would come to about $27,057 MXP (Amortization 2011). If the household achieves immediate savings of $200 pesos (I will keep this constant, but contributing factors, especially gas prices are always subject to change) while requiring $75/month in payment, that household would realize immediate net savings of about $125/month. This

[10] The 215MXP figure also includes potential savings from energy efficient light bulbs, low flow appliances and other "eco-technologies" included in the Green Mortgage Program.

[11] These numbers are not the same for all homeowners and depend on a number of factors such as monthly income, age, and specific line of credit. Interest rates vary from 4-10% and 30 years is the maximum term for a mortgage. The idea here is to illustrate ballpark estimates using relatively typical numbers

saving would then last for 30 years or until the solar heater stopped working. In other words, if all goes well, the homeowner would receive an immediate net savings of $125 MXP/month with the package of eco-technologies compared to if they were not installed. Calculating a simple payback period using the $14,000 loan and $200 in savings, these SWHs could be paid off in as little as 5.8 years. However, there are many factors that need to be considered in addition such as the prices of gas, amount of hot water required, interest rates, timeframe of the loan, lifetime of the system, the effect on the retail value of the home and the exact method used to calculate the payback period.

As are Infonavit mortgages in general, the Green Mortgage program is explicitly aimed at middle to lower income workers and homes are only eligible for Green Mortgage financing if they cost less than $611,374.40 Mexican Pesos-MXP (about $48,909 USD). The homes in the subdivisions examined in this study cost between $200,000 and $260,000 MXP.

The initiation of the "Green Mortgages" (Hipotecas Verdes) program was the first major step taken by INFONAVIT to encourage the use of solar water heaters in their homes. The criteria used to qualify a home for the program are specific to the region of the country in which the home is located, and are determined based on the climatic zone and which type of technologies would be most appropriate in that specific region. Solar water heaters are a substantial part of the package in 18 states, including Oaxaca.

While the Hipoteca Verde program is described as an additional credit that is lent to the borrowers, it seldom appears to function in that manner. Instead, it appears to serve more as a designation for the homes that meet these requirements because potential

homebuyers can often qualify for this relatively small additional loan without the need to invoke this program. In this way, the Green Mortgage program seems to be a more important term for discussions between INFONAVIT and the contractors building the new homes than it is for home-buyers and owners. In fact, when speaking to the residents of several developments with homes designed based on the GM standards, the vast majority of the residents stated that they had never heard of the Green Mortgage program. This was found to be true in both the San Jeronimo and Ranchos de Lago del Valle *fraccionamientos*, where all of the homeowners I spoke with had homes purchased under the Green Mortgage program. When speaking with the executives of the Oaxacan Infonavit office, they stated that while consumers should be informed of the term, it rarely functioned as an additional credit for the home-buyers.

Recently, however there appear to have been significant changes made so that all new Infonavit mortgages will go towards homes that use these eco-technologies. The headline on the front of the Infonavit website which used to provide a link to "Green Mortgage" section now states "All Infonavit Credits will be Green". In this section of the website, they state that in 2011, "homes should be equipped with eco-technologies independent of the type of credit chosen."

In general, the Hipoteca Verde (Green Mortgage) program as it was functioning during the time of the research, appeared to be an effective measure designed to promote the use of innovations such as solar water heaters in new homes across Oaxaca and Mexico. As we will see, however, it is one thing to get the systems on the roof, and

another to properly explain them to everyone involved, keep them maintained, and ensure that they function as planned.

25,000 Solar Roofs Program

New homeowners who purchase a home through the "Green Mortgage" program and make less than $6,987.13 pesos a month (about $550 USD; this amount was set at exactly four times the minimum wage in Mexico City) are now eligible to receive a direct subsidy on the purchase of a solar water heater through the program "25 Thousand Solar Roofs". This program again expands the scale of the transition process to the international scale as the funds are being distributed through the GTZ, and the program was developed as part of the International Initiative for Climate Protection (ICI). The subsidy is planned to cover a part of the cost of new solar water heaters and last through 2012.

During an interview with an employee of the GTZ I was informed of the planned subsidy breakdown, consisting of 7,500 subsidies to be distributed during 2010. The updated website shows that the project does not appear to have given out as many subsidies in 2010 as was planned, and they have subsequently revised the breakdown of how the subsidies will be distributed (Table 4).

It is also interesting to note that the actual amount per subsidy is set to decrease each year. GTZ indicated that one reason why he believed the program would be able to offer smaller amounts per subsidy is because as the technology scales, "every year the technology should become cheaper"

Table 4: Breakdown of the subsidy program "25,000 Solar Roofs in Mexico"
The program is sponsored by the GIZ through the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

	Subsidy (Pesos/Unit)	# of Subsidies (Planned)	# of Subsidies (Revised)
2010	2000	7,500	2,033
2011 New Homes	1600	10,000	10,000
2011 Used Homes	2100		5,467
2012	1000	7,500	7,500
	TOTAL	**25,000**	**25,000**

The funds from this program are primarily financed by the German Government's Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety (or BMU), while the real impetus for investing in a project of this nature comes from the German climate protection program the International Climate Initiative (ICI). Under this program, the German government has created an annual fund of EUR 120 Million (Bmu.de) generated through the auctioning of emissions allowances, based on the EU Emissions Trading System. This money is then invested in environmental initiatives in developing and newly industrializing nations.

Figure 10: Infonavit Building in Oaxaca

I was able to speak with several employees of the INFONAVIT office in Oaxaca who provided some interesting insight into how the national plans to increase solar water heaters are being implemented on the local level. Jorge is an accountant with Infonavit who has also purchased a home in a local *fraccionamiento* through the Infonavit Green Mortgage program. He said has seen the potential for solar water heaters for a long time and even had one installed in his home in the 1980's that functioned pretty well. While he seems to be pretty positive overall about the *Hipotecas Verdes (Green Mortgage)* program, and the potential for solar water heaters in Oaxaca, his personal experiences reveal potential problems as the policies become implemented.

Within the last year, Infonavit employees were offered a low-interest loan of about 17,000 MXP that could be used to purchase and install a solar water heater for their home- effectively the equivalent of the additional loan made available through the Green Mortgage program. While not all of the 42 employees took advantage of this offer, about ten of them did, including Jorge. He had his installed about 5 months before I first spoke with him, but due to a faulty connection, the device did not function properly for several months after it was installed by the contractors. He contacted the contractor, informing them that the device was never installed properly, but was completely rebuffed. The contractor responded that their work on that project was done to their satisfaction and they would not come back to fix it. Jorge was obviously frustrated and angered, but could not get the original contractor to come and fix his heater. After several months he finally contacted a different company who, for a price, came out and fixed the faulty connection.

While the personal account of Jorge is certainly telling as to the problems individuals face when purchasing SWHs, he also pointed out a larger structural problem that may be present in the Hipoteca Verde program. He believes that since construction companies already know how much additional lending Infonavit is willing to loan through the HV program, they are simply raising the prices of the homes by that exact amount (around 17,000 pesos) instead of installing these systems at a more competitive price. This additional cost to each home is used to cover the cost of the SWH, water saving shower heads, LED lights, and higher quality insulation. He believes that the price being charged is not being competitively priced and is probably too high for what is

being provided, and that this represents a possible inefficiency in the HV program. It does not encourage competitive pricing among different contractors for these eco-technologies.

This example shows how problems may arise when implementing policies, even for people directly involved in the policy and who know it well. JLFGs heater was purchased through a very small scale policy offered only to direct employees of Infonavit itself. The problems he has experienced may be greatly enhanced when the policy is ramped up to a much larger scale, and have the potential to create a ripple effect of negativity surrounding the use of solar water heaters.

Normex (The National Organization for Standardization and Certification) and ONNCCE (The National Organization for Building and Construction Standardization and Certification) are the agencies responsible for regulating and setting the standards for certifications of solar water heaters in Mexico. This process is very helpful for creating an industry based on products that people can trust. As the process of diffusion of innovations relies heavily on peer-to-peer interactions and discussions of the technology, faulty systems can have widespread effects, hampering efforts aimed at achieving social acceptance of the technology. These agencies are responsible for preventing this situation from occurring.

ONNCCE, for example, is responsible for producing a Dictamen de Idoneida Técninca (Technical Capacity Report) describing the characteristics and performance of all SWHs to be used in programs affiliated with Procalsol policy. This report certifies that each type of SWH used meets specific requirements of the Procalsol policy and provides an estimate for the potential for energy savings.

POLICY RESULTS

Since Procalsol policy was implemented in 2007, it has officially been qualified as a success. According to an employee of the GTZ, the goals for installed systems have been met, and even surpassed each year after 2007. He explained that they have adjusted their stated goals upward every year, and all of those goals have also been met. To illustrate this trend he told me that in 2007, about 1,800 SWH systems were installed through the Hipoteca Verde program throughout the country, but by 2009, the program was led to 37,000 new installations. Additionally, the *25,000 Solar Roofs* program is beginning to come into effect and will lead to actual subsidies for 25,000 new systems over the next three years. This program, he explained will be aimed to encourage SWH heaters in states where "number of SWHs installed wasn't as significant as it was in other states". Looking forward, there are hopes that these policies will be expanded to housing sectors that are currently not eligible for subsidies or loans under these programs. Beginning in 2012, for example the subsidies under the 25,000 Solar Roofs program are slated to become available for retro-fitting existing homes, as well as for housing complexes or homes over three stories high.

As the massive efforts to formulate this policy come into effect, however, how are these newly installed units actually functioning on the ground? And how are the homeowners that are being introduced to them for the first time perceiving and understanding the new technology? In the following chapter I will explore these issues by examining how the Procalsol policy has affected the residents in several areas of the city.

Chapter 6: A Variety Of Experiences And Perceptions Of an Artifact

A Tale of Two Subdivisions: San Jeronimo and Rancho del Lago

About 15 miles both east and west of Oaxaca City, two housing developments are being constructed among the farmland and small towns of the central Oaxacan valley. These private developments of around one thousand homes each are designed for potential homeowners to purchase with mortgages financed through the national mortgage agency Infonavit. The majority of residents I encountered were young couples or families of moderate incomes, working in middle class positions as teachers, mechanics, police officers, shopkeepers, or food vendors with little prior knowledge of solar water heaters. In fact none of the residents I spoke with had used a solar water heater prior to their experiences in these developments, so it was here that they were encountering and forming perceptions of this technology for the first time.

This section will explore how new homeowners, using solar water heaters for the first time, have come to understand, perceive, and use the technology. Through a series of interviews with residents in two subdivisions, I found that there was a stark difference in how the solar heaters were performing, and therefore how they were perceived, in each of these respective locations. It should come as no surprise that attitudes relating to the solar water heaters were much more positive among users with a fully functioning apparatus while for many of the residents in the subdivision with faulty systems, there were general misunderstandings related to what these systems were and what exactly they were supposed to do. Additionally, this section will explore the financial impacts these

heaters are having at the household level, and contrast these new developments with a neighborhood that is not being affected at all by the activity surrounding solar water heaters.

SAN JERONIMO SUBDIVISION

"No complaints. On the contrary we thank them for implementing these systems. The only people who are complaining are the people who didn't get one with their home…"

Figure 11: San Jeronimo Subdivision

About 15 miles west of Oaxaca City, the small town of Yahuiche takes on the feel of a smaller village with a slower pace than its urban neighbor. Dogs sleep on the side of beaten dirt roads and rows of maize line the small plots of land between houses. This small town feel, however, quickly fades into a bright suburban style landscape as

hundreds of identical white concrete homes rise up from the surrounding green valley. These homes, part of a private development project by the development firm Premier Capital and construction firm Cocopsa, are exclusively sold through Infonavit supported mortgages. The project had begun several years before, but when the Hipoteca Verde program came into effect in 2009, all of the new homes began to be installed with solar water heaters.

In general, the people in this *fraccionamiento* (essentially a planned subdivision) appeared to be genuinely content with their solar water heater and the way it functioned. The residents that I spoke with had been living in this development for an average of about nine months (no longer than a year), and eight out of the homes I spoke with relied solely on the solar water heater for their domestic hot water without ever turning on the boiler. Residents here were generally confident in their knowledge of how these devices worked and supported the notions that they offered both economic and environmental benefits. Although the developers did not fully explain these systems to most of the homes I spoke with, everyone had a functioning system and expressed similar ideas concerning how they perceived them; positively. Not a single resident expressed any initial complaints concerning how their unit functioned. When pressed, a few respondents indicated that the water does not come out hot when it is cloudy for several days, but anyone who made this claim also clarified that it always came out warm enough so that it was never uncomfortable to shower with. The experiences of one family highlight many of the ideas expressed by residents in this subdivision.

Ruben, a restaurant worker in Oaxaca City, has lived in the San Jeronimo with his wife and young boy for about five months. I began by asking him how his unit has been working. "It's working well. Everything is good. Actually my assessment is that, I feel like it's a real help for the planet because now you aren't polluting with the gas. Now you're not…well…Me, financially, I am saving money on gas, and the water comes out just as hot as if I were heating it up with gas. For me it's the same thing."

Figure 12: Improperly installed SWHs
All systems are supposed to be oriented towards the south, which is clearly not the case in the photo above.

He bought his house precisely as the developers decided to qualify the remaining units for the Green Mortgage program by equipping them with SWHs and other required eco-technologies. His main concern was that the price of the home increased significantly after the developers told him that the Green Mortgage packet of eco-technologies would be included. This concern seemed to be tempered by how well he

has found these systems to work, so that this initial price increase, which made him think of not purchasing the home, has come to be part of a long term investment in the home and the water heating technology. It also highlights how his experience with the technology has led to changing perceptions of what the technology is and how it functions.

> Because it is financed through a mortgage, they have to make some money on the loan too…Maybe if I had the money I would go out and buy a system for cheaper with cash, but unfortunately I don't…And plus, now I know that they work because I have lived with one and see it, but if someone were to just tell me about one of these things I wouldn't believe anyone so easily.

RANCHO DEL LAGO DEL VALLE

Figure 13: Rancho del Lago subdivision

A similar distance to the east of the city, another large housing development is underway that is also installing solar water heaters on all of their homes. While the product that they are installing is similar in both locations, the way the heaters are performing is a true study in contrasts. In fact, none of the homeowners I spoke with in this development had a functioning solar water heater, although they had most of the necessary equipment on their roof. As in San Jeronimo, these developers had to experiment with several SWH manufacturers before settling on the brand that they are now using. The first manufacturer they used built systems with glass casings, but when

the tanks filled with water, these systems became top-heavy and several systems collapsed and broke. About one week before my visit the developers switched to a new system constructed with a polycarbonate case which is lighter and more durable. However, the problems related to the use of solar water heating technology in this location appear to have less to do with the technical components of the technology, and more to do with a lack of effort and communication on the part of the developers.

This development is a very new project with ongoing construction in process and very sparse occupation rates. Again, a large portion of these residents were young couples or families who had recently moved here from Oaxaca City, and were still working in Oaxaca City, commuting by either bus or collective taxi. Of the ten households I interviewed, the average time of residence in the development was only about two and a half months, and no one had lived there for more than four months. With no prior exposure to solar water heaters, the homeowners' experience with this technology has been brief but decidedly negative. In fact, I did not encounter a single resident who had a properly functioning system. Although all but one of the units I encountered did have the physical apparatus on the roof, none of them were functional. Several units also reported that the boiler, which was supposed to serve as a backup system, was not functioning either and they had to bathe with cold water.

Part of this problem may stem from a lack of communication between the developers and residents regarding how the technology is supposed to be used. In fact, none of the residents reported that they had been properly instructed about how the heaters operated. This combination of encountering the technology for the first time, not

having it properly explained, and malfunctioning technology has led to different ideas concerning what this technology is and how it is supposed to function.

This sense of confusion about this technology is apparent in the many ideas concerning how these devices worked and what it meant for the device to be properly functioning. Even basic ideas about what how the heaters function were apparently not communicated to several residents. For example, one resident told me that "We still haven't connected it to a gas tank so it isn't working yet." This fundamental misunderstanding about how the heaters work means that the potential benefits, both economic and environmental, that may be derived from this system are not being communicated to, or realized by, the people who are actually using the systems.

One resident in the Rancho del Lago subdivision, a young mother of two small children, initially responded that she thinks her system appears to be working, but that it has some defects. She went on to explain that when they had their system connected they would not get hot water, except for every once in a while when very hot water would come out of both the hot and cold faucets so that when turning on water from either faucet, "you have to kind of guess…" She described this level of functioning as having "disadvantages" and tended to view this technology as a sporadically functioning machine that is unreliable and potentially dangerous.

Another resident told me that the people from the office had explained to him that the technology was basically a storage device. He said that instead of having to heat water with the boiler right before taking a bath, with this device he could heat water at any time and the solar heater would store it until it was needed. From his perspective,

this technology was defined as a container that stored hot water. In this case, information regarding the technology was communicated, however that information was simply incorrect and led to more confusion concerning what this device was actually supposed to do.

The example of one couple is illustrative of the problems many residents have faced. Enrique and Pamela are a married couple in their early twenties from Oaxaca City where they both continue to commute for work every day as a mechanic and a teacher respectively. They have lived on the second floor of a Rancho del Lago duplex unit with their small daughter for about four months, and seem almost eager to speak with me about the host of problems they have encountered with the building. In addition to a leaky roof, missing light bulbs (that were supposed to be a part of the Hipoteca Verde package), and problems with the boiler, the solar hot water heater has never been properly connected. Pamela explained how one day a property manager had come by to tell them that they were going to install a solar water heater, but did not explain anything about it to them. In their experience, the water would only come out hot once in a while, but when it did "it would come out hot, hot ,hot, hot and there was no way to cool it down". After complaining to management and speaking with a neighbor they were left confused about how these heaters were supposed to work and why they had purchased a home with these systems to begin with. "We just thought we were going to save money and that we could do without some luxuries (gas) to make our living expenses more accessible." Their experiences with this technology have not born out this prediction,

and this disappointment is part of how many people are encountering this technology in this location.

While no policy is perfect, there are clearly components of this policy that are allowing for significant problems such as unwarranted costs, defective systems, and incompetent contractors. If these problems persist, and people continue paying for systems that simply do not work, there is a risk of creating a highly negative public perception of the technology. This would clearly pose a severe problem for achieving the goals of the Procalsol policy, and possibly hinder any future programs designed to promote energy efficiency. In fact studies have shown that negative experiences with a technology can do far more damage to its diffusion than positive experiences can do to increase diffusion (Mallet 2007).

In a previous study, Mallet (2007) found similarly problematic circumstances surrounding solar water heaters in Mexico City. Mallet determined that the negative perceptions of the technology could have far reaching implications on its overall level social acceptance. She explains that:

> The fact that certain cheaper versions of SWHs in Mexico (whether locally made or imported) are of poor quality has had a profound effect on the social acceptance of SWHs from bad experiences with the technology-due to bad installations, or a poorly working system…Some perceived this technology to be "written off" as it simply did not work…

The case of the Rancho del Lago subdivision may not be representative of the overall progress or accomplishments of the Hipoteca Verde program, but it is what I witnessed during my research in Oaxaca. A report published by Infonavit based on data from up to April of 2011, indicates that about 92% of respondents evaluated their

experience with their SWHs as "good" or "very good" with only 3% of respondents indicating "bad" (Infonavit 2011). It is possible that I stumbled upon a section of that 3%. Nonetheless the problems being experienced in this subdivision point to issues that can arise, and should be controlled as much as possible if the HV program is to succeed.

OTHER COLONIAS

"…as long as the supply of more essential goods and services is insufficient, the supply of hot water is a less pressing issue and is regarded as a luxury. As long as no running water is available, the usefulness of SWH is very limited. Thus, aid for the dissemination of SWHs does not address the poor but the ones with higher income" (Langniss and Ince 2004).

In Mexico, many of the policies being implemented, such as the Green Mortgage Program and 25,000 Solar Roofs, have been aimed at incentivizing the use of these systems for working class families. A representative of the GTZ explained that "…right now there is a focus on sustainability in the housing market and the government is helping out so that they can install the systems for families in low-income houses." This is what appears to be happening. However, in the case of Rancho del Valle, I would contend that the developers appear to be benefitting more from the use of solar water heaters than the working class families who are living there. The developers are getting paid for these units whether they are working or not, just as the people living there are paying for them whether they are working or not. And while I was there, several months after many people had moved in, the systems were not working.

Everett Rogers explains that the diffusion of innovations usually leads to increasing inequality in a social system (Rogers 2005, p456). A primary reason for this is that the people encouraging the diffusion of the innovation tend to work closely with:

> If a change agent were to contact the poorer and less educated individuals in a social system, rather than the socioeconomic elites (as is usually the case), the benefits from the innovation that are so introduced would be more equal. Usually, however, change agents have most contact with the better-educated, higher status individuals in a system, and thus tend to widen socio-economic gaps through the innovations they introduce.

While there is clearly significant development and technological changes taking place in the fraccionamientos outside of Oaxaca, many areas of the city seem to be receiving significantly less government attention. The State of Oaxaca is one of the poorest states in Mexico, (Inegi.org) and much of this poverty is also seen throughout Oaxaca City; especially among the home made settlements and homes that dot the steep hills surrounding the city. Many of these areas receive no electricity or water service, let alone subsidies for any type of solar (or any variety of) water heater. In the context of Oaxaca, where many residents do not have access to more essential goods and services, a supply of solar hot water is truly far from the most pressing issue facing the city. Scholars have pointed out this disparity while studying emerging solar water heating markets in developing countries and generally agree that hot water is often regarded as a relative luxury and are not the ideal technology to enhance the living conditions of the poor in developing countries (McEneely 2000, Langniss and Ince 2004).

I spent several days speaking with residents living in one area on the steep slopes of the hills, on the far western reaches of the city, to get a better sense of areas clearly not being affected by the Procalsol policy. Although I had spent nearly two years previously living in the city, I had never visited this difficult to reach area. One morning, I jumped on the bus, got off at the last stop on the line, and began to walk up the steep pavement. Eventually the paved roads all died out and I continued walking up the dirt road, still big enough for cars to drive on. I stayed on this road, passing concrete and wooden homes and steadily climbing up the hill over-looking the city. Soon, concrete homes gave way to earthen and tin structures; chickens and dogs and turkeys were on the road and in front of every home. Goats were around, but more rare, and by now the view of the city was impressive.

Deep rivulets cut down the side of the hill from the rains and the roads had massive potholes and tire tracks filled with water. I started up another narrow dirt road that was winding its way up the hill and from this road I could see a lady tending to a fire and a bunch of kids hanging from trees. The house they were standing to the side of had a wooden frame- a thin sheet metal roof, and a mix of sheet metal siding and some concrete-block work. The sheet-metal panels were nailed in with bottle caps as a sort of washers. The house was built up on an earthen ledge that rose off the road about a foot.

I passed the kids and took a few steps down another little trail before turning back and walking past the kids again to where the lady was tending to the fire. I approached her, spoke briefly about the nice view, and told her a little bit about my project. She asked me several questions and seemed interested. The lady, Angelica, then explained to me

that she was actually now burning trash and some wood to heat water to bathe in. I asked if she would mind if I came and took a look at what she was doing. "Pasele", she said and I stepped up onto the level of the house and little dirt patio area and could see the little fire on the ground with a pot of water being heated on it. We talked a little about it and she said that this is what she uses to heat water to bathe with everyday.

By this point there were several little kids gathering around us. I asked how many people lived there and she said they were 13. Some of the teenage boys in the family work and pitch in with money for the house. Of the 8 kids I met, 3 were her grandkids and the rest were her own kids. Her husband works in construction, and many of the others worked if not in the neighborhood exactly, at least close enough by.

She explained that they had been living in this spot for about 15 years, and while they have had electricity for about 6-7 years, the home still does not have water or telephone service. We chatted for a little bit- I told her a bit about the SWHs and then she said to pass inside and they will make me some tacos. I told her that sounded good, but only if they let me pay for them. "Yea, no worries" she said, "you can pay later". I went towards the house- not really knowing what to expect.

I stepped inside and immediately noticed that the ground inside was the same dirt as the road and patio. My first step brought me into a small kitchen area with a gas powered stove and a fridge. The bulk of the house consisted of an open area which was sort of divided in two by an armoire, which served as a sort of wall. On the side closer to the kitchen was a table and chairs and on the other side were three twin/double beds. The bathroom was off to the side and it did have tile floors. In front of the bathroom was a

washing area- a sink and clothes dryer. I looked around for a bit before sitting at the table and being served a plate of black beans with two jumbo portions of *tasajo* (thickly sliced beef), a bowl of salsa, a *tlayuda* (a giant Oaxacan tortilla), white bread, *atole (a thick rice or oatmeal based warm drink),* cold soda, and jalapenos.

Anjelica talked about how she personally knows Gabino Cue, the newly elected governor, because she used to work in a house where the owner was friends with Cues mom. She said he is good people and comes from a good family that people in Oaxaca know and like. After the meal, several of the kids sat with me at the table and played games. Between them, they had tons of games to play and I have no doubt we could have played for the rest of the afternoon and into the night. After many rounds of several games, I excused myself and went back to talk to Angelica- who had been keeping busy the whole time cleaning, giving hints, and generally making sure the house was up and running. I thanked her for all the hospitality and asked if she had time to answer a few of my questions.

While she seemed genuinely interested in the idea of solar water heaters, she felt the upfront cost would make it difficult to purchase. For this family, as for the urban poor in general, a solar water heater would be a relative luxury that would not address her family's more immediate needs. She began to explain how she basically burns all of the trash that they produce here and use the fires to heat up water to bathe in. Then she uses the ash from the fires to plant vegetable seeds- chiles, corn, beans- which she grows in the ground outside the house. She said her family is from the Mixteca- but not the Alta but from the area before you get to Nochixtlan from Oaxaca- and while she was born and

raised in the city she used to go and spend her summers out with her grandparents and she learned how to take care of crops and animals and she still likes to do that. She still speaks passable Mixteca, but her grandparents speak it fluently.

She also talked about how access to water is a problem here. During the rainy season they catch water from the roof- most if not all of the houses in the area had rainwater catchment systems- but during the dry season they have to pay around 200 pesos every 15 days to a guy who drives around with a water truck and fills up their water (2500+liters). This is many times more expensive than it is for homes with regular municipal water service.

The bathroom in the house was improved in the last few months so that now there is a concrete wall enclosing it. There was a pipe that takes the shower water directly to water the plants in front of the house, but the toilet water goes somewhere else- down some type of drain to somewhere…

Figure 14: A home with a hand-made rainwater collection system.
Homes on the steep hills on the outskirts of Oaxaca City often do not receive municipal services such as water or electricity. They are able to purchase water from a truck, but prices are many times higher than water that is piped in. This home (which is not the exact one described above) has designed a rainwater collection device from corrugated steel pieces and tied onto the roof.

She seemed pretty glad that they were able to take advantage of the little they had, and was proud of the efficient system she had developed for using all of her available resources-collecting rainwater from the roof, burning the trash to heat the water, planting seeds in the ash from the fires, and watering the plants with water right from the shower. She really had developed an entire system of complimentary functions that created very little total waste. While this family may never own a solar water heater, their life style requires much less consumption and waste than occurs in many of the homes that do use this technology.

Figure 15: Water being heated outside a home.
The water, used primarily for bathing, is being heated by by burning firewood and trash.

UNINTENDED EFFECTS OF DIFFUSION OF AN INNOVATION

When an innovation is introduced to a society it is difficult to tell what the ultimate direct and indirect effects it may lead to. Studies throughout the world have illustrated these unintended consequences of technologies relating to environmental, economic, and social concerns (Rogers 2003).

One critique of the use of technology for achieving environmental gains involves the application of Jevons Paradox, which holds that as technological advancements increase the efficiency of a resource, consumption of that resource actually tends to increase. For example, as cars become more efficient, people may tend to drive more, leading to an overall increase in the consumption of gasoline. This idea was first

formulated by William Jevons in his 1865 book The Coal Question, examining the use of coal in a rapidly industrializing England. He found that the technological efficiency gains which allowed for a more "economical" use of coal actually led to increases in the overall consumption of coal, iron, and other resources (Alcott 2005). There is now little debate that when efficiency gains are introduced the savings generally amount to less than the actual amount of efficiency gains. In other words, if cars become 30% more efficient, there may be a 20% savings in energy consumption. This is known as the "rebound" or "take-back" effect. However, some economists argue that this effect may extend beyond the initial efficiency gains, leading to overall increase in consumption, known as the "backfire" or "boomerang" effect (Alcott 2005).

For example, in a more recent and closely related study on the emerging use of clothes-washing machines in China, Lin and Iyer explain how these clothes washers may be causing dramatic increases in household energy use as they often have built-in water heating components as domestic hot water is often not available. This study further illustrates how "the adoption of foreign technologies and technical standards, if not carefully calibrated to the local cultural practices, could have unintended consequences for energy use and the environment" (Lin and Iyer 2007).

Is it possible that the increasing use of solar hot water heaters in Oaxaca may lead to increased consumption of gas for hot water or water in general? People may want to use more hot water for washing clothes and dishes if they have access to cheap cheap hot water. Then, they may use more hot water than the solar heater alone can provide. It may also lead to increase in water use in general. Perhaps for example, people will now

begin to take longer showers. Or, as people begin waiting for the shower to get hot before stepping in, several minutes may pass with the colder water going down the drain. Will Oaxacans become more accustomed to washing dishes and clothes with hot water, eventually requiring more hot water than these systems were designed for, leading to an increasing use of the gas back up system until more gas is required than before with a traditional boiler used only for showers? These possibilities are just a few possible examples of negative consequences that could arise from the increasing use of solar water heaters in Oaxaca.

In addition to possible unforeseen negative consequences, there may also be unexpected positive effects. For example, in their study of SWHs in China, Han et al (2010) found that SWHs may reduce the high incidence of rheumatoid arthritis, which is mainly attributed to the current use of cold water for laundry and dish washing. In sum, then, it is clearly difficult to know what effects a given technology may engender in a society. As solar water heaters continue to spread throughout Oaxaca and Mexico, it will be advisable to at least keep be aware that there may be unintended consequences associated with their use.

Chapter 7: The Private Marketplace

So far we have seen how people in Oaxaca tend to view and use hot water, how a specific policy was implemented to encourage the use of solar water heaters, and how that technology has been experienced by the final users in Oaxaca. However, in addition to the rising use amongst the segment of the population that is buying new Infonavit homes, there has also been an emerging private retail market where solar heaters are sold directly to individuals or businesses. This market appears to have risen in close conjunction, at least temporally, with the changes brought about by the Procalsol policy and has therefore grown rapidly within the last 2-3 years.

This chapter will analyze this private solar water heating market by examining some key participants such as hardware shops, alternative energy shops, home-owners, hotels and tortilla manufacturers. Throughout, I hope to emphasize the potential connections between these places and groups and the individuals living in the *fraccionamientos* who are already living with solar water heaters because of the Procalsol policy.

The residents in these neighborhoods typically continue to work and spend a significant amount of time in Oaxaca City interacting with people who do not use the solar devices. It is these interactions, between adopters and non-adopters that really drives the diffusion process of innovations. Everett Rogers explains that "the heart of the diffusion process is the modeling and imitation by potential adopters of their near peers' experiences with the new idea. In deciding whether or not to adopt an innovation,

individuals depend mainly on the communicated experience of others much like themselves who have already adopted a new idea" (Rogers 2003). In fact, the way that new users of this technology perceive it may have a greater affect outside of the home or building than on the actual structure where it is being used. There are clear associations between people beginning to use solar hot water heaters and those using any of the more traditional systems for heating water in Oaxaca. The information shared about the solar water heaters through peer to peer contact has been identified as a key component in the overall process of diffusion of innovations (Rogers 2003)

As residents begin to experience the new solar heating technology, they are forming perceptions of the technology, based largely on the type of water heating system they had previously used, in order to assess the relative advantage of the new technology. Normally, potential adopters of a new technology will try to assess the possible relative advantage when deciding whether to adopt a new innovation, however in this case, the new users generally made the decision to purchase a home, and the solar water heater simply came with it. In some cases, the homeowners were skeptical or even against the idea of having to pay for solar water heating on their new homes. So, now these residents with this new technology must assess the relative advantage of this system once it has already been installed on their home.

Relative advantage (consisting of factors such as economic profitability, low initial cost, a decrease in discomfort, social prestige, a saving of time and effort, and immediacy of reward) has been shown to be one of the strongest influences in the process of diffusion of innovations (Rogers 2003 p 233). Thus, two fundamental components of

Rogers' diffusion model consist of the assessment of the relative advantages of the innovation, and the peer-to-peer exchange of that information which "lies at the heart of the diffusion process" (Rogers 2003 p 233). So, as new users adopt a technology and compare it to the previous system, they will generally share that information with their peers, and this sharing of information forms the strongest variable in assessing whether the non-adopters will eventually adopt.

Most people purchasing solar water heaters without government support are experiencing them for the first time and are faced with some basic questions before deciding to make any purchase. The common sense questions facing the majority of Oaxacans choosing whether to adopt this technology are A) Does it function properly? B) How much does it cost up front? C) Will it save money over the long run in reduced gas use? As we will see, the answer to these questions is highly dependent on a number of specific circumstances.

Solar water heaters are now on display or for sale in almost all of the large-scale hardware stores throughout the city[12]. None of these stores carried solar water heaters prior to the implementation of Procalsol just three years prior. Additionally, Oaxaca now has three stores dedicated exclusively to the provision of alternative energy technologies. One of these stores, SolarMaxx, opened in the summer of 2009 and works exclusively in the sale and installation of solar water heaters. While it is difficult to trace the direct link

[12] In this context I am referring to the large hardware stores-nearly all of which have multiple locations in the city- as opposed to the small mom and pop type hardware stores.

between the Procalsol policy and the emergence of these retail markets, it does appear that there is some association between the two phenomena.

HARDWARE STORES

Jutting up from the roof of nearly every home and building in the city, steel rebars are an ever-present part of the Oaxacan urban environment. Representing both the financial difficulties of fully completing any construction project, and the eternal optimism for a better future, rebar gives most residential neighborhoods the feeling of a work-in-progress. The ubiquitous sounds of construction further attest to the feeling of transformation through construction projects. In the poorest neighborhoods, scrap metal shelters may be gradually turned into concrete homes, while more established homes may add a new bedroom for a growing family. Planned communities, including ones with solar water heaters, are often designed to structurally support additional floors that may be built on later (San Jeronimo for example incorporated a sun-roof designed to allow for a future stair-case and was engineered to allow for the construction of a second floor.) Small scale construction and home-improvement projects are ubiquitous throughout the city, and are often done through small contracting companies or by the homeowners themselves. Recently, the hardware stores that supply home-improvement and renovation materials also began to experiment with selling solar water heaters. Surveys and personal interviews conducted throughout the city shed some light on the role of these hardware stores as Oaxacans increasingly learn about and gain interest in solar water heating technology.

Figure 16: Two copper panel SWHs on display in a hardware store.
These systems are both equipped with an on-demand gas system that automatically switches on if the water from the solar system is not hot enough.

Table 5: Hardware Stores Selling solar Water Heaters in Oaxaca City

	150 LITER COPPER MXP[13]	150 LITER GLASS MXP	TIME SELLING SWHS (YEARS)	#SOLD LAST YEAR	PLAN TO CONTINUE SELLING	ON DISPLAY[14]
Ferretubos	12,500/9,500[15]	--	1	2	Y	Y
Los Picos	--	8,200	2	1	Y	N
Construrama	--	9,599	2	15	Y	N
Gurrion	--	8,900	.5	3	Y	Y
GEO	--	7,744	5	4	Y	N
ZZetuna	14,632	--	--	--	Y	Y
Acuatica P	11,000	--	--	10	Y	Y
IEASA	9,571	4,699	3	4	Y	Y
SolarMaxx	--	--	1	30+	Y	Y
Enalto	--	--	6	3	Y	N

Solar water heaters are generally available and fairly visible throughout the main hardware stores of the city. Due to the sheer number and variety of hardware stores, I will not attempt to assign a percentage of hardware stores that carry them; there are simply too many small mom-and pop stores and the difficulty of equating such a shop with some of the larger stores would make it nearly impossible to accurately assess what

[13] Several stores also sold heaters of various sizes from 66-320 Liters
[14] Several stores have more than one location. This column shows whether they are displayed at any branch
[15] This price includes a backup on-demand gas based heater

percentage of "hardware shops" carried them. However, in the majority of the larger stores they are at least available for purchase and sometimes even prominently displayed.

Solar water heaters are currently sold in at least six distinct hardware stores throughout the city; *Ferretubos, Apasco, Grupo Electrico de Oaxaca, ZZetuna, GCG, and GEO*. Many of these larger stores are actually chain-stores with several locations, so that in reality solar heaters are available in over a dozen distinct hardware shops. Generally, however, the most central location is the main center for the sale of SWHs. The more peripheral locations will direct interested clients to the central location for more information on SWHs. ZZetuna, for example, has three locations in the city, each of which is capable of selling solar water heaters, but they are only on display in the most central location. APASCO also has several locations, but the only manager that could give me any information regarding their line of SWHs was in the most central location. Similarly, the central Construrama had a SWH on display until very recently and continues to sell them from that location, while the other locations preferred to direct me to the central location instead of sell them.

Managers of these stores indicated that they had only been carrying solar water heaters for an average of just over 2 years at the time of my research. Over the last year, the stores had sold anywhere from 1-15 solar water heaters. Although I regret not speaking with more customers within these shops, I did get the chance to interview the managers about their interactions with customers relating to solar water heaters and why people did or did not ultimately make the purchase. In this regard, the costs appear to be the most important factor affecting customers' decisions. The high upfront cost was

consistently described as the reason most people did not purchase the heaters, while the potential for long-term savings was described as the key factor for most people who did buy a system. While the potential for reducing environmental impact was mentioned by several managers as an additional consideration for some of their clients, it always came up in conjunction with potential economic savings. One manager explained that "People are not as concerned about the environment aspects. What they really want to know is if it is economical" Based on a generalized average cost plus installation total of about $12,000MXP, and $200 MXP in monthly gas savings, these systems may be able to pay for themselves in about 5 years.

Figure 17: SWH on the roof of a private home

ALTERNATIVE ENERGY SHOPS

In addition to the various general hardware stores found throughout the city, there are also three stores in Oaxaca that exclusively sell alternative energy technologies; SolarMaxx, ENALTO (Energías Alternativas Limpias de Oaxaca or Oaxacan Clean Energy Alternatives), and IEASA (Ingeniería Eléctrica Alternativa Sustentable or Alternative Sustainable electrical Engineering). One of these shops, SolarMaxx, is solely dedicated to selling solar water heaters. This shop opened one year prior to this research, and has achieved substantial success within the last year catering to both private residences and hotels. These shops are also split on the issue of glass vs. copper heaters; SolarMaxx carries only the glass tube model, while another specialty shop carries only copper and the third carries one brand of each model.

I was able to spend significant time in each of these shops and interview the owners of each of the three. At one point, the owner of SolarMaxx described why he got into this business and what it may require to succeed:

> it requires diffusion in such a way that the government has to be involved… We need more education about the natural environment, about how to take care of our world. …I mean, you don't need the degree to be intelligent. A lot of the people that live up in the mountains have a lot of wisdom and they imagine and think and accept what really exists. Just like there is ignorance, there is competence…Everybody needs to participate to develop a civic consciousness so that everyone can collaborate and participate so we can do what we need to do for our world. At any given moment, we don't know whether in twenty or thirty years, this whole thing might run out…we have children and those children have children and those children have children--so what are we going to give our children. We can teach and guide and tell them how to avoid big problems and catastrophes. We take out millions and millions and millions of liters of petroleum from the earth. So imagine if you go multiplying that for every hour, day, year… You say "man what are we doing?" We're trying to help a little bit…

Figure 18: "Solar Energy" sign in Oaxaca.
ENALTO stands for "*Energías Alternativas Limpias de Oaxaca"* ("Oaxacan Clean Alternative Energies"). This shop is one of three in the city that deal exclusively with alternative energy equipment. One of these three, SolarMax, only works with Solar Water Heaters.

HOTELS

Hotels make up a large portion of the current clients in this private solar water heater market. While I was not able to obtain a full breakdown of the clients by any of the shops that I spoke with, I was informed several times that hotels make up a significant portion of the SWHs being sold in Oaxaca. As part of my research, I spent several days with an installation crew, installing SWHs on the roofs of two hotels in the *centro historico* area. The owner of one of the hotels told me that water heating was a large expense for the hotel. She had installed a couple of units about a year ago and seen an overall decrease in her water heating expenses and felt that she would recoup the money spent on the heaters within the next year. Based on that experience, she was now

installing a larger commercial size (300 liter tank) unit, and placing it so that it was visible from the street. She told me that not only were the heaters going to save her money every year, but they were a selling point to potential customers. The other hotel that I spent time working on echoed similar sentiments, but had less actual experience with the heaters. Nonetheless, this hotel was covering virtually the entire rooftop with 13 commercial grade units.

Figure 19: SWHs being installed on the roof of a hotel

Figure 20: Installing an evacuated tube SWH on the roof of a hotel

TORTILLERÍAS

Although I was not able to find any tortilla manufacturers using solar water heaters, I believe they should be included in any broad discussion of potential beneficiaries of this technology in Oaxaca. These tortilla makers are small shops that are usually independently run and provide tortillas to neighbors. There seems to be one within walking distance of just about any point in the city, and they are all large consumers of gas for water heating. Some of them may spend up to $10,000 MXP a month for water heating. This is a significant expense, and while solar water heaters can not get water to the boiling temperatures needed to prepare the *masa* for tortillas, they can heat water up to 80˚C, taking a significant burden off the gas boilers. This issue has even been recognized by the federal government, which in January of 2011, announced a $500

Million MXP subsidy program designed to provide up to 20% of all small and medium sized tortillerías to purchase solar water heaters(CNN Expansion 2011). So, although I was not able to find any tortillerías in Oaxaca who were using SWHs, they do deserve to be taken into consideration, especially as this new subsidy program gets under way.

This new private market for solar water heaters in Oaxaca has really emerged over the last two years, in conjunction with the subsidy and incentive programs associated with Procalsol. Over the coming years, it will be interesting to see how this market interacts with the growing market in the Infonavit mortgaged subdivisions. Will problems in the Infonavit market create a negative perception of the technology that stunts growth in this private market? Will the growing use of SWHs in Infonavit lead to a growing awareness and acceptance of the technology, as well as economies of scale which can significantly lower the price? These questions and more remain to be answered over the course of the next several years.

Chapter 8: Conclusions

The emergence of solar water heaters in Oaxaca is clearly a complex process involving a wide range of participants and moving parts. Throughout this paper, I have tried to paint a broad picture of some of the important actors and activities surrounding the use of SWHs during the time of my research. My goal has been to take a particular moment in history, and try to understand part of the overall process that is leading to a rising use in this particular technology. Solar water heaters did not just begin to appear on the rooftop of Oaxacan homes in 2008; that was only one part of a longer history and ongoing process that many different stakeholders are still competing to influence. In order to attempt to conceptualize this process, I have drawn from previous works coming from several distinct perspectives. In my concluding remarks, I would like to briefly relate my findings back to these original ideas about the nature of technological change.

How do Innovations Diffuse?

Solar water heaters are diffusing throughout Oaxaca through two distinct markets; 1) pre-equipped on homes purchased through Infonavit backed mortgages, and 2) purchased in the private market where SWHs are individually sold through hardware and specialty alternative energy shops. While the mechanisms that are guiding the diffusion process through these two markets are quite different, ultimately, the interactions between these two markets may be the most important factor impacting the diffusion of solar water heaters in Oaxaca.

In the Infonavit market, consumers essentially face very little choice concerning whether or not to adopt this technology. This market generally consists of salaried workers attempting to purchase the home that makes the most sense for them based on the location and their personal finances. The fact that they are participating in the Green Mortgage program or buying a home with a solar water heater is often unknown or secondary to a number of other concerns related to the purchase of a new home. These new homes are installing SWHs on a large scale (over a thousand per development) and are more impacted by government policy than by explicit decisions by residents to purchase a solar water heater.

Within this market, people are generally experiencing SWHs for the first time and without conducting much prior research about the technology. We have seen how the residents in two separate Infonavit subdivisions are actually experiencing SWHs in drastically different ways. In the San Jeronimo subdivision, the SWHs are functioning properly and people appear to be happy that they are spending far less (or nothing at all) on gas for water heating each month. However, residents of the Rancho del Lago subdivision are having quite the opposite experience. Here, none of the solar water heaters have been properly installed and the residents are understandably confused and upset about the expensive piece of equipment sitting on their roof.

The other market for solar water heaters in Oaxaca consists of what I have labeled the "private market". The private market for solar water heaters in Oaxaca has really arisen over the course of the last several years, in close conjunction (temporally at least) with the emergence of the Infonavit, policy-based market. In this private market, affluent

residents of Oaxaca, and commercial enterprises such as hotels, are purchasing hot water heaters from a number of hardware stores and alternative energy specialty stores throughout the city. These consumers are making an explicit decision to purchase these heaters versus the other options that are available to them. For most, this means considering a balance of potential economic and environmental benefits of the SWHS compared to traditional gas based heaters[16]. The actual amount of benefit achieved depends on a number of factors specific to the users (such as hot water usage) as well as external factors (such as the price of Gas LP). No matter what type of benefits they do or do not achieve, in this private market they are only available for residents who can afford to defer these potential benefits for several years into the future, as there are only very limited financing options.

As these two markets continue to grow, they will also continue to interact and influence one another. If significant problems persist in the Infonavit market, this could lead to a generally negative public perception of the technology and cripple the chances of achieving widespread adoption. For now, people who are purchasing the heaters in the private market may be motivated by other factors than pure economics (i.e. environmental) and can afford to make that decision. However, for many Oaxacans, the decision to adopt a SWH will be motivated more by financial concerns. If this private market is to attract a more mainstream base, it cannot afford to allow SWHs to have a negative perception as a risky investment.

[16] hotels also consider them a selling point, just as high end consumers may consider them a sort of status symbol

A Socially Constructed Artifact

I believe that throughout this study we have seen several examples which suggest that the term "solar water heaters" means different things to different people. Participants in this process, from homeowners to the International Copper Association, are still negotiating the meaning of this technology. In effect, the meaning of "solar water heater" is still in the process of being constructed by a number of different social groups and influences.

For example, homeowners experiencing the technology for the first time have been shown to have different conceptions of what the technology means based on a variety of different factors. In one sense, we have seen that Oaxacans have nuanced values about hot water in general, which translates into different views on solar water heaters. For some people, it is almost useless because they prefer to bathe with cold water, while for others it is a great way to save money and gas. Interestingly, these nuanced views on hot water may actually encourage increased social acceptance of solar water heaters. As less people require "very hot" water all year round, more of these people may be inclined to adopt SWHs as a way of providing them with sufficient hot water based on these preferences. Other homeowners have assigned different meanings to the technology because of their actual experiences with it. For the residents of San Jeronimo, it is generally viewed as an efficient machine for achieving economic and environmental savings. Residents in Rancho del Lago on the other hand, had a variety of meanings for solar water heaters; one resident misunderstood them as way to store water

that has already been heated by gas, and for others they were a symbol of the contractor's incompetence.

In addition to ways in which new homeowners perceive the technology, the physical form that the heaters take is also in the process of being negotiated. While there has been a general stabilization around the idea of using a direct-passive thermosiphon system, we have seen how there are currently two main versions of this technology available in Oaxaca: glass and copper. While there are pros and cons to both forms, only the copper form had a major representative (Procobre, the Latin American branch of the International Copper Association) play an important role in shaping the Policy to Promote the Use of Solar Water Heaters in Mexico. The developments I visited all used copper heaters, while stores throughout the city offered both versions, although glass was more widely available.

Through the examples of home-owners perceptions, as well as the competition between glass and copper versions, we have seen that the meaning of "solar water heater" is still being negotiated and constructed in the emerging Oaxacan market.

An Actor-Network

I think one of the most important lessons to draw from this broad study is the simple realization that it takes a wide network of supporting actors to allow a given technology to take root in a society. The International Copper Association, a German aid organization, the price of gas LP, new homeowners in Oaxaca, shop-owners, installation crews, and policymakers are just a few of the pieces that have to work together to create

the system that is now taking shape in Oaxaca. Changes in any of these inter-related components can lead to a wholly different configuration of the entire network, affecting the form of the technology used and how the technology interacts with society. For example, without the presence of the International Copper Association in formulating the Procalsol policy, perhaps more people would be using glass based systems, and having different experiences with them.

We should also remember that this broad network as I have tried to describe it is constantly changing and rearranging itself. Actor-network Theory notes that the apparent stabilization of any network is a result of relationships between all of the participants that need to be constantly reaffirmed. As these relationships shift, and new participants become involved, the network supporting solar water heaters in Oaxaca will take on new configurations. With so many participants making up this network it is truly impossible to tell what will happen to the current momentum behind the use of SWHs in Oaxaca. For example, what will happen to the price of Gas LP? This has the potential to significantly alter the economics and decision making process for potential adopters outside of the subsidized market, yet there is no way to accurately assess how prices, or any number of other factors, will change over the next several years.

A Three-Tiered Perspective on Technological Change

One way to analyze the process of how societies change from using one form of technology to another is to think of events occurring on three different interacting analytical levels. Significant change can happen when the overarching contextual level

(landscape), disrupts the dominant technological system (regime), and provides an opportunity for emerging technologies (niches) to replace or compete with the regime.

Several Landscape-level changes occurred in Mexico and Oaxaca over the last decade that have provided opportunities for the rising use of solar water heaters. Economically we can identify at least two major factors. First of all, during the early to mid-2000s, when the research for the Procalsol policy was initially being carried out, the price of Gas LP in Oaxaca was rising very rapidly. In fact from 2001 to 2006, the price per liter of gas more than doubled from $4.51 to $9.07 MXP/lt. (Prices have since relatively leveled off and currently stand at 10.44 as of July 2011). Several reports about solar water heating policy were then produced by 2006, and the Program to Promote the Use of Solar Water Heaters was established by 2007. In fact, the second figure in the entire Procalsol document is a chart indicating the rising price of gas since 2002 (Procalsol 2007, p 9). Clearly, then the rising price of gas weakened the structure of the gas based hot-water system enough to allow SWHs to become perceived as a viable option in Mexico.

An additional landscape-level economic change occurred as the overall strengthening economy in Mexico led to a massive surge in the new housing market. The formal sector of the housing market (homes purchased from developers or agents, with mortgaged financing- as opposed to homes built by the owner mainly using remissions) grew by about 45% from 2001 to 2004 (Hoyt et al 2006). This is substantiated by a similar rise of 50% in mortgages taken out between 2001 and 2005, with a majority of these going towards the purchase of new homes. This rapid growth in the new housing market created an additional opportunity to promote solar water heaters that could then be financed as part of these long term mortgages.

Another landscape level change can be seen in the increasing focus on environmental issues; globally, nationally and locally. The international focus on global environmental issues, and specifically the issue of climate change, has directly impacted the issue of water heating in Mexico. The primary example of this can be seen by the presence of the German aid organization GIZ throughout the entire research, planning, and implementation stages of Procalsol. The investment of time and money by this agency is supported through the German climate protection program the International Climate Initiative (ICI). Under this program, the German government has created an annual fund of EUR 120 Million (Bmu.de) which is generated by auctioning emissions allowances, based on the EU Emissions Trading System. This money is then invested in environmental initiatives in developing and newly industrializing nations. Without the support of GIZ, it is unlikely that there would a Procalsol policy at all.

On the national level, Mexico ratified the UNFCCC in 1993, developed a National Action Plan for Climate Change in 1997, ratified the Kyoto Protocol in 2000, called for environmental care in the energy sector through increasing the use of renewable energy in the National Development Plan 2001-2006. The more creation of the Special Program on Climate Change in 2009 indicates that these efforts are ongoing. All of these actions have provided a favorable political climate for the passage of a policy to promote the use of solar water heaters in 2006, and have had direct or indirect impacts on the current gas based water heating regime.

This regime is based on networks of gas trucks which drive around the city delivering gas to individual homes and businesses as it is demanded. This system uses limited natural resources, and is responsible for 4 million tons of CO2 equivalent

emissions per year, while costing citizens about $49 Billion MXP (about $4B USD) in fuel per year (Procalsol 2007, p 8)[17]. As the landscape level changes impacted this regime, solar water heating was provided with a window of opportunity to compete with this dominant system.

Modernizing (Ecologically)

As modern society confronts growing environmental problems, people have developed a wide range of perspectives related to how these issues should best be approached. For some, the patterns of production and consumption associated with modern society are simply incompatible with a system of life that exists within the carrying capacity of the earth. Arguments from this perspective may call for structural changes to our economic, political and social infrastructures. At the other end of the spectrum, some people believe that the only way to solve the environmental problems of modern society is to continue to modernize and rely on technologically based solutions.

The Procalsol policy is based primarily based on this latter approach, sometimes referred to as ecological modernization. Based on this research, then, can we say that the emergence of SWHs in Oaxaca has or will lead to net environmental benefits? As with the answer to so many difficult questions, I believe the answer to be both relative to the context being discussed and dependent on a number of factors that are out of the scope of this research or impossible to predict. (So, unfortunately the simple answer consists of two clichés, "it's relative" and "it depends"…)

Compared to the most commonly used source of water heating in Oaxaca, the gas boiler, SWHs, when installed properly, operate using far less fossil fuel inputs. Proponents of solar water heaters often claim that they can provide 60-80% of the hot

[17] These numbers are accounting for water heating across all sectors of the economy.

water needed throughout the course of a year by a typical family. I encountered several SWH users who reported that they had not used their boiler a single time throughout the year they had been living with the SWH, a 100% reduction[18]. In this sense, solar water heaters have the potential to drastically reduce the amount of Gas LP used for domestic water heating across the residential sector of Mexico and Oaxaca. However there are also a number of reasons to be cautious about claiming complete environmental success.

First of all, solar water heaters are a thing. They rely on raw materials, are manufactured, delivered, and eventually disposed of or recycled. This entire life-cycle process requires energy. Additionally, they are almost always equipped with another thing, a gas-based heater, that functions as a back-up. So, in the end solar water heaters as they currently function are not in homes *instead* of gas-based heaters, but *in-addition* to them. In this way, SWHs require an increase in production and consumption compared to the current system.

Additionally, it is difficult to say with certainty, but I believe SWHs have the potential to lead to a net increase in the consumption of water in Oaxaca in two ways. First of all, while I have not read any empirical studies on this issue, I believe it is reasonable to speculate that as hot water becomes relatively cheaper per unit used per household, households will simply begin to consume more hot water, and hence consume more of another scarce resource, water itself. This phenomenon is explained by the application of Jevons paradox, which states that as a resource is used more efficiently, overall consumption of that resource tends to increase over time. Another possibility leading to an increasing use of water is an indirect effect. If the increasing use of SWHs

[18] A recent report published by Infonavit indicates that about 47% of HV residents do not use the gas backup system at all. About 24% of respondents use it about once a week and18% every 1-3 weeks. 11% of respondents indicated that they use the gas back-up system every day (Infonavit 2011). These numbers do seem to roughly correlate with my findings.

leads to more people bathing in hot water that used to prefer cold, will there be a significant amount of water wasted as people wait for hot water to circulate through the pipes before they begin to shower (water which these people used to jump right into)? These are both speculative concerns, yet potential areas to be cautious about when evaluating the overall environmental effects of the increasing use of SWHs in Oaxaca.

POLICY

The significant problems being encountered with solar water heaters in the Ranch Del Lago subdivision should signal an alarm for policy makers about how this policy is being implemented and evaluated. Commenting on similar issues with solar water heaters in other locations, Roulleau and Lloyd have called for a re-evaluation of the metrics for successful policy implementation. They argue that instead of merely counting the number of units installed, incentive programs should make attempts to get better measurements of overall system *performance* before counting units as successful. They note that:

> …subsidy regimes conducive to expanding system numbers and deployment alone does not indicate either whether the systems are working well or reducing overall national energy consumption. Instead of subsidizing purely in terms of the collector area, some countries have chosen to subsidize the systems as a function of solar performance… (Roulleau and Lloyd 2008).

This idea could have real implications for both policy makers and for the successful diffusion of the technology. If more residents continue to have significantly negative experiences with these systems, social acceptance of the technology may be

significantly hindered. When installed and used correctly, SWHs can provide both environmental and economic benefits at the household level. I found that both of these values are very important to Oaxacans and thus, there does appear to be potential for continued growth of this technology in this region.

In order to attempt to fix some of the problems facing the implementation of the Procalsol policy, I would suggest creating a stronger oversight mechanism to ensure that systems are not only installed, but installed properly. Random checks of subdivisions by a mobile team of supervisors appears to be one simple approach. In a matter of days, a representative could check on a number of developments and get a better sense of how the systems are functioning and how the residents are responding. Alternatively, it may be helpful to design an online system where residents can register from their specific subdivisions and report on how their system functions. With all of the time and money spent on promoting these policies, I believe any additional amount spent on strengthening the oversight process would be well worth it. In fact, a recent report about the status of the Hipoteca Verde program indicates that clear steps are made in this direction. While there were only 120 and 158 visits to homes with newly installed SWHs in 2009 and 2010 respectively, this number has soared to about 688 visits in 2011 (Infonavit 2011).

I have also pointed out a few ways in which this technology can have unintended environmental circumstances. The growing use of this technology should be monitored with a critical eye to ensure that the benefits associated with its use outweigh any potential drawbacks. Additionally, we have seen that there are areas of Oaxaca with a lack of access to even basic municipal services such as water, electricity, and or

telephone lines. Policy makers should weigh the benefits of promoting the use of solar water heaters against providing these basic services to people who would greatly benefit from them in their everyday lives.

If this technology does continue to expand in Oaxaca, it will be interesting to see how co-evolution processes develop. Will the use of this technology help foster a growing environmental consciousness in general? How will Oaxacan ideas of what constitutes appropriate technology shape the final form of the technology? Technology alone will not lead to sustainable patterns of consumption. However by gaining a better understanding of the relationship between specific societies and technologies, and how a society's values are "made durable" through the systems of technology that they employ, we can better situate the role of technology in this process.

As technologies in fields such as energy, information, and telecommunications continue to play an increasingly important role in modern society, it will be important to gain a better understanding of the complex relationship between these technologies and the type of society we want to live in. Overall, I believe the main takeaway from this paper is that technology should not be isolated and studied as an independent variable used to assess how "technology affects society". Instead it is one part of a complex network (comprised of human economic processes, political systems, human relationships, materials, etc…) that make-up the world we live in. In this network, where everything is connected, we should be careful about oversimplifying causal relationships and attributing changes to any one factor. Technology is just one of the many important factors that support our society's existence and allow it to function as it does.

Glossary

ANT	Actor-Network Theory
CONUEE	Comisión Nacional para el Uso Eficiente de la Energía (National Commission for the Efficient Use of Energy)
BM	German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
MLP	Multi-level Perspective
SCOT	Social Construction of Technology
EM	Ecological Modernization
GTZ	German Society for International Cooperation (Deutsche Gesellschaft für Internationale Zusammenarbeit)
MXP	Mexican Peso ($1MXP = approximately $.085 USD)
USD	United States Dollar ($1USD= approximately $11.76MXP)
ICI	International Climate Initiative
HV	Hipoteca Verde (Green Mortgage)
SWH	Solar Water Heaters
Procalsol	The Program for the Promotion of Solar Water Heaters in Mexico
Sener	Mexican Secretary of Energy
Semarnat	Mexican Secretary of the Environment and Natural Resources
Oaxaca	Oaxaca de Juárez, the capital city of the State of Oaxaca.

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